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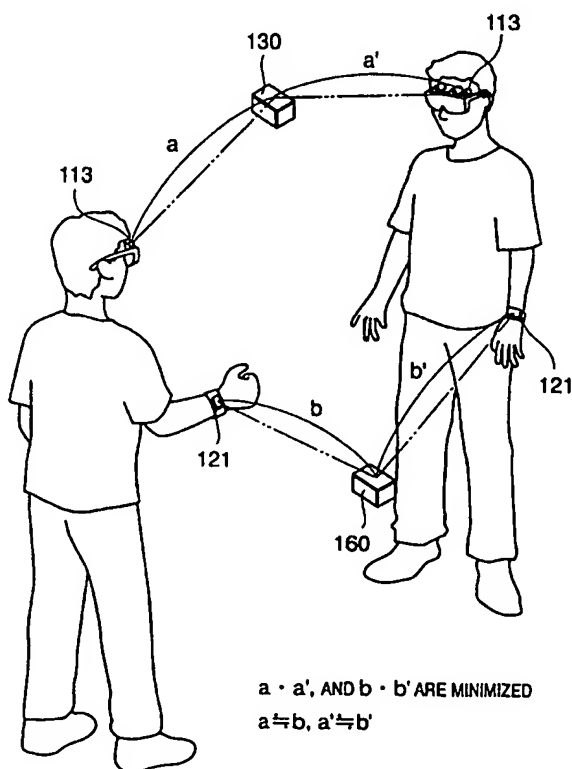
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(54) Title: **MIXED REALITY SYSTEM WHICH REDUCES MEASUREMENT ERRORS OF VIEWPOINT POSITION AND DIRECTION OF OBSERVER**

$$a \cdot a', \text{ AND } b \cdot b' \text{ ARE MINIMIZED}$$

$$a \approx b, a' \approx b'$$

(57) Abstract: ABSTRACT A mixed reality system which reduces positional shifts between a real space picture and a virtual space picture with an inexpensive arrangement is disclosed. The mixed reality system according to this invention detects the viewpoint position and direction of an observer and the position and direction of another region of the observer by using reception results on signals output from a transmitter. In this mixed reality system, the transmitter is positioned such that the distance between the transmitter and a receiver used for the measurement of the viewpoint position and direction of the observer becomes shorter than the distance between the transmitter and a receiver used for the measurement of the position and direction of another region of the observer. This makes it possible to reduce measurement errors of the line-of-sight position and direction which are more dominant over positional shifts.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DESCRIPTION

MIXED REALITY SYSTEM WHICH REDUCES
MEASUREMENT ERRORS OF VIEWPOINT POSITION AND
DIRECTION OF OBSERVER

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TECHNICAL FIELD

The present invention relates to an augmented or mixed reality system which creates and displays a mixed reality space picture by combining a real space picture
10 received from a video camera or the like and a virtual space picture created by CG or the like, and a head mounted display apparatus which can be used for the mixed reality system.

The present invention also relates to a method of determining the position of a transmitter used to measure
15 the position and direction of a predetermined region of an observer in the above mixed reality system.

BACKGROUND ART

In a mixed reality system, to merge a real space with
20 a virtual space, the 3D coordinates and direction of a real space object by using some means. As methods of acquiring these pieces of information, for example, the following method are realized: a method using a position/direction measurement apparatus typified by FASTRAK (trademark)
25 available from Polhemus Inc. in the US, a method of combining information obtained by image processing of a real space picture based on known camera parameters with

information obtained by a gyro, and a method of measuring the position and direction of a real space object by using a special multi-eye camera.

Apparatuses used in these methods are expensive, and
5 besides, have measurement errors. To reduce such measurement errors, a measurement apparatus which is more expensive rather than cost-effective is required, which is one of the factors that hinder a reduction in the cost of a mixed reality system.

10 Fig. 22 shows an example of how a conventional position/direction measurement apparatus typified by FASTRAK available from Polhemus Inc. in the US.

Referring to Fig. 22, reference numerals 300a and 300b denote observers; 301, an HMD (Head Mounted Display)
15 used by an observer to observe a mixed real space; 302, a position/direction measurement receiver mounted on the HMD 301; and 304, a position/direction measurement transmitter hidden by a wall. The observers 300a and 300b stand to face each other in a set 310. Each observer can freely determine
20 a viewpoint position and line-of-sight direction within a movable area 311.

Reference numeral 312 denotes a mixed real space picture observable area. When the observer 300a or 300b sees this mixed real space picture observable area 312,
25 he/she can observe, through the HMD 301, a mixed real space picture obtained by merging a CG picture as a virtual space picture with a real space picture. When the observer does

not see the mixed real space picture observable area 312, only a real space picture is displayed on the HMD 301. A virtual space picture is displayed at a position determined on the basis of the viewpoint position and line-of-sight direction of the observer. It is therefore important to reduce measurement errors of the viewpoint position and line-of-sight direction when the observer sees the mixed real space picture observable area 312.

As shown in Fig. 22, if, however, the receiver 302 is fixed to the left side of the HMD 301 to measure the viewpoint position and line-of-sight direction of an observer, the distance between the receiver 302 and the transmitter 304 becomes long. This may result in an increase in measurement errors.

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DISCLOSURE OF INVENTION

The present invention has been made in consideration of the above problem in the prior art, and has as its object to reduce positional shifts between a real space picture and a virtual space picture with an inexpensive arrangement.

According to the first aspect of the present invention, a mixed reality system which creates and displays a mixed real space picture by combining a real space picture with a virtual space picture, characterized by comprising a transmitter, a first receiver which receives a signal generated by said transmitter to measure

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a viewpoint position and direction of an observer, and a second receiver which receives a signal generated by said transmitter to measure a position and direction of another body region of the observer, wherein said transmitter is
5 positioned such that a distance between said transmitter and said first receiver becomes shorter than a distance between said transmitter and said second receiver.

According to the second aspect of the present invention, a head mounted display apparatus which is used
10 in a mixed reality system that creates and displays a mixed real space picture by combining a real space picture with a virtual space picture, and which can mount a receiver used to measure a viewpoint position and direction of an observer to be mounted, characterized in that a plurality of mount
15 portions for detachably mounting said receiver are formed.

According to the third aspect of the present invention, a method of positioning a transmitter in a mixed reality system which includes the transmitter, a first receiver which receives a signal generated by the
20 transmitter to measure a viewpoint position and direction of an observer, and a second receiver which receives a signal generated by the transmitter to measure a position and direction of another body region of the observer, and creates and displays a mixed real space picture by combining
25 a real space picture with a virtual space picture, characterized in that said transmitter is positioned such that a distance between the transmitter and the first

receiver becomes shorter than a distance between the transmitter and the second receiver.

BRIEF DESCRIPTION OF DRAWINGS

- 5 The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.
- 10 Fig. 1 is a view showing the schematic arrangement of a mixed reality system to which the third embodiment of the present invention is applied;
- Fig. 2 is a view showing the arrangement of an HMD;
- Fig. 3 is a flow chart showing the processing of
15 creating a mixed real space picture;
- Figs. 4A and 4B are views showing a real space picture example and virtual space picture;
- Fig. 5 is a view showing an ideal (with no error in position sensor measurement values) mixed real space
20 picture corresponding to the real space picture example and virtual space picture example in Figs. 4A and 4B;
- Fig. 6 is a view showing a mixed real space picture corresponding to the real space picture example and virtual space picture example in Figs. 4A and 4B in a case where
25 an error exists only in an eye position sensor measurement value;
- Fig. 7 is a view showing a mixed real space picture

corresponding to the real space picture example and virtual space picture example in Figs. 4A and 4B in a case where an error exists only in a hand position sensor measurement value;

5 Fig. 8 is a view for explaining the distance relationship between a position sensor transmitter and a position sensor in the first embodiment of the present invention;

 Fig. 9 is a view for explaining the distance
10 relationship between a position sensor transmitter and a position sensor in the second embodiment of the present invention;

 Fig. 10 is a view for explaining the distance relationship between a position sensor transmitter and a
15 position sensor in the third embodiment of the present invention;

 Fig. 11 is a view showing the schematic arrangement of a mixed reality system to which the third embodiment of the present invention is applied;

20 Fig. 12 is a view showing the schematic arrangement of a mixed reality system to which the fourth embodiment of the present invention is applied;

 Fig. 13 is a view for explaining the distance relationship between a position sensor transmitter and a
25 position sensor in the fourth embodiment of the present invention;

 Fig. 14 is a view showing the schematic arrangement

of a mixed reality system to which the fifth embodiment of the present invention is applied;

Fig. 15 is a view for explaining the distance relationship between position sensor transmitters and
5 position sensors in the fifth embodiment of the present invention;

Fig. 16 is a view showing the schematic arrangement of a mixed reality system to which the sixth embodiment of the present invention is applied;

10 Fig. 17 is a perspective view showing a case where the HMD according to the sixth and seventh embodiments is viewed from the direction of a photographing unit;

Fig. 18 is a perspective view showing a case where the HMD according to the sixth and seventh embodiments is
15 viewed from the direction of a display unit;

Fig. 19 is a block diagram showing a hardware arrangement corresponding to one observer in the system shown in Fig. 16;

Fig. 20 is a view for explaining the mount position
20 of a position sensor (receiver) in the sixth embodiment of the present invention;

Fig. 21 is a view for explaining the mount position of a position sensor (receiver) in the seventh embodiment of the present invention; and

25 Fig. 22 is a view for explaining an example of a problem in the prior art.

BEST MODE OF CARRYING OUT THE INVENTION

Preferred embodiments of the present invention will now be described in detail in accordance with the accompanying drawings.

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[First Embodiment]

Fig. 1 is a view showing the schematic arrangement of a mixed reality system to which the first embodiment of the present invention is applied. An observer 100 is
10 wearing an HMD (Head Mounted Display) 110 on the head and a glove 120 on his/her hand.

As shown in Fig. 2, the HMD 110 is comprised of a video camera 111, LCD 112, position/direction measurement apparatus receiver (eye position sensor) 113, and optical
15 prisms 114 and 115. The video camera 111 photographs a real space picture at/in the viewpoint position and line-of-sight direction of the observer through the optical prism 115. The eye position sensor 113 is used to measure the viewpoint position and line-of-sight direction of an
20 observer. The LCD 112 displays a mixed real space picture. This picture is guided to the pupil of the observer through the optical prism 114.

The glove 120 incorporates a hand position sensor 121 and speaker 122 (not shown). The hand position sensor 121
25 is used as a sensor for measuring the position and direction of the hand of the observer. The speaker 122 generates a sound corresponding to an event that has occurred at the

position of the hand. This sound may be a sound generated when the user touches or hits a virtual space object with his/her hand, a sound generated when the condition of a virtual space object displayed in synchronism with the position of the hand changes, or the like.

Reference numeral 130 denotes a position/direction measurement apparatus transmitter (position sensor transmitter); and 131, a position/direction measurement apparatus body (position sensor body). The eye position sensor 113, hand position sensor 121, and position sensor transmitter 130 are connected to the position sensor body 131. Magnetism is transmitted from the position sensor transmitter 130. This magnetism is received by the eye position sensor 113 and hand position sensor 121. The position sensor body 131 calculates the position and direction of the eye and hand on the basis of the reception intensity signal from the hand position sensor 121. As this position/direction measurement apparatus, FASTRAK available from Polhemus Inc. in the US or the like can be used.

Reference numeral 140 denotes a processing apparatus for creating a mixed real space picture for one observer and displaying it on the HMD 110. This processing apparatus 140 is comprised of, for example, a personal computer, a video capture card, a video card having a CG function, a sound card, and the like. The HMD 110, speaker 122, and position sensor body 131 are connected to the processing

apparatus 140.

A procedure for creating a mixed real space picture in the processing apparatus 140 will be described next with reference to the flow chart of Fig. 3.

5 First of all, the processing apparatus 140 receives a viewpoint position, a line-of-sight direction, and the position and direction of the hand transmitted from the position sensor body 131 (step S301). Note that the operation in step S301 uses thread S311 of periodically
10 receiving the viewpoint position, the line-of-sight direction, and the position and direction of the hand transmitted from the position sensor body 131.

The virtual space time is then updated, and the state of the virtual space (the type, position, and condition of
15 a virtual space object) is updated (step S302). In this case, if there is a virtual space object whose position and direction change in synchronism with the position and direction of a real space object, the state of such an object is also updated. If, for example, the user is made to see
20 that he/she is always wearing a glove as a virtual space object on his/her hand, the position and direction of the glove are updated in accordance with changes in the position and direction of the hand in step S302.

If the relationship between the position and
25 direction (the hand position and viewpoint position) of the real space object and the position and direction of the virtual space object is then checked, and it is determined

that a predefined event has occurred, the state of the virtual space is updated in accordance with the event (step S303). For example, the occurrence of an even corresponds to a case where it is determined that the user touches the
5 virtual space object with his/her hand. Updating the state of a virtual space in accordance with this event may be equivalent to changing, for example, the picture of the touched virtual space object into a picture of an explosion.

A real space picture at/in the viewpoint position and
10 line-of-sight direction of the observer which is obtained from the video camera 111 is received (step S304). This operation in step S304 uses thread S314 of periodically acquiring the real space picture obtained from the video camera 111 through a video capture card.

15 A virtual space picture at/in the viewpoint position and line-of-sight direction of the observer, which are obtained in step S301, is created in accordance with the state of virtual space updated in steps S302 and S303 (step S305).

20 Finally, the virtual space picture created in step S305 is combined with the real space picture received in step S304, and the resultant picture is output to the LCD 112 of the HMD 110 (step S306). The above processing is repeatedly executed until some terminating operation is
25 performed (step S307).

A method unique to this embodiment will be described next, which is used to reduce the differences in position

and direction between a virtual space object and a real space object in a mixed real space picture observed by each observer.

If the position/direction measurement apparatus can
5 properly measure the viewpoint position and line-of-sight direction of an observer and the position and direction of the hand, there are no differences in position and direction between the virtual space object and the real space object. Consider the real space picture shown in Fig. 4A and the
10 virtual space picture shown in Fig. 4B. In this case, ideally, a mixed reality picture like the one shown in Fig. 5 is created. In practice, however, the position/direction measurement apparatus uses magnetism or ultrasonic waves, and hence is very susceptible to
15 disturbances and has a small measurable range. The actual position/direction measurement apparatus can measure with effective accuracy only within a range of about 80 cm from the position sensor transmitter. It is also known that even in measurement in a space without any ferromagnetic object,
20 position and direction measurement errors monotonously increase with an increase in distance between the position sensor transmitter and the position sensor (receiver). In order to improve this situation, it is important to minimize the distance between the position sensor transmitter and
25 the receiver.

Measurement errors in the position/direction measurement apparatus pose a more serious problem in the

measurement of viewpoint position and line-of-sight direction. If measurement errors about the hand position and direction increase, only a positional shift occurs between the hand the virtual space object that moves in synchronism with the hand, as shown in Fig. 7. If, however, measurement errors about the viewpoint position and line-of-sight direction increase, positional shifts occur with respect to all virtual space objects as well as a positional shift with respect to the hand, as shown in Fig. 6.

The principal object of the first embodiment is therefore to improve the measurement accuracy of the eye position sensor 113. To reduce positional shifts between a real space object and a virtual space object, the position sensor transmitter 130 is placed such that the distance between the eye position sensor 113 and the position sensor transmitter 130 becomes shorter than the distances between the position sensor transmitter 130 and the remaining sensors connected to the position sensor body 131 at the positions and directions at/in which the respective position sensors are used with high frequencies, as shown in Fig. 8, thereby improving the measurement accuracy of the viewpoint position and line-of-sight direction as compared with the measurement accuracy of the position and direction of the remaining position sensors. This makes it possible to make positional shifts with respect to all the virtual space objects less noticeable.

The position of the position sensor transmitter 130 cannot be specified but should be changed flexibly depending on the type of mixed reality picture the mixed reality system displays and the position and direction
5 viewed by an observer.

Assume that a plurality of observers exist. In this case, mixed reality can be further augmented by setting a situation in which the observers can observe each other. In general, therefore, the direction in which each observer
10 observes with a high frequency becomes the horizontal direction. In such a situation, placing the position sensor transmitter 130 above the head of the observer as shown in Fig. 8 makes it possible to have the merits of this embodiment and prevent a picture of the transmitter, which
15 should not be combined as a real space object in the mixed real space, from being combined. In addition, this allows the observer to freely move in all directions. Furthermore, since measurement errors caused when the observer moves become equal to each other in all directions, management
20 is facilitated. As described above, a mixed real space picture without any unnecessary real object, which has high quality as a whole, can be observed while the freedom of movement is ensured.

25 [Second Embodiment]

The second embodiment exemplifies a case where a position sensor transmitter 130 is placed such that the

distance from a hand position sensor 121 is shortened, as well as the distance from an eye position sensor 113, at/in the viewpoint position and line-of-sight direction at/in which the hand is observed with a high frequency and at/in
5 the hand position and direction, as shown in Fig. 9.

In the second embodiment, in a situation where an observer frequently observes the hand, the position sensor transmitter 130 is so placed as to shorten the distance between the eye position sensor 113 and the position sensor
10 transmitter 130 as well as the distance between the hand position sensor 121 and the position sensor transmitter 130. This makes it possible to reduce measurement errors in both the eye position sensor 113 and the hand position sensor 121. As compared with the first embodiment, a virtual space
15 object that moves in synchronism with the hand can be observed while the object is localized on the hand with a small error.

Obviously, the posture of an observer in which the hand is frequently observed depends on the contents of a
20 mixed real space picture which the mixed reality system is to present to the observer. For this reason, the position sensor transmitter 130 must be adjusted such that the distance from the hand position sensor 121 becomes almost equal to the distance from the eye position sensor 113 when
25 the hand is frequently observed.

This embodiment has exemplified the case where the position of a virtual space object is changed in synchronism

with the hand. However, the present invention is not limited to this, and can also be applied to a case where the position of a virtual space object is changed in synchronism with another body region such as a foot.

5

[Third Embodiment]

Fig. 11 is a view showing the schematic arrangement of a mixed reality system to which the third embodiment is applied. This system is based on the assumption that two
10 observers simultaneously observe the same mixed real space. This system includes two systems each identical to the one shown in Fig. 1. Note that a position sensor transmitter 130 and position sensor body 131 are shared by the two observers to realize a reduction in the total cost of the
15 mixed real space system. The position sensor body 131 is connected to only one processing apparatus 140 and is not connected to the other processing apparatus 140. For this reason, the processing apparatuses 140 for the respective observers are connected to each other through a network 150
20 to allow the processing apparatus 140 to which the position sensor body 131 is not connected to create a mixed real space picture.

In the third embodiment, as shown in Fig. 10, at the position where each observer observes a hand with a high
25 frequency, the position sensor transmitter 130 is so placed as to almost match the distance (a or a') between an eye position sensor 113 for each observer and the position

sensor transmitter 130 with the distance (b or b') between
a hand position sensor 121 and the position sensor
transmitter 130. In addition, the position sensor
transmitter 130 is so placed as to minimize the respective
5 distances (a, a', b, and b').

With this arrangement, each observer can observe a
virtual space object that moves in synchronism with a hand
with a small position shift on the hand.

Note that positional shifts can be made uniform with
10 respect to all observers by placing the position sensor
transmitter 130 such that the distance (a) between the eye
position sensor 113 for a given observer and the position
sensor transmitter 130 becomes almost equal to the distance
(a') between the eye position sensor 113 for the other
15 observer and the position sensor transmitter 130, and the
distance (b) between the hand position sensor 121 for a
given observer and the position sensor transmitter 130
becomes almost equal to the distance (b') between the hand
position sensor 121 for the other observer and the position
20 sensor transmitter 130.

The procedure executed by each processing apparatus
140 is almost the same as that in the first embodiment except
that the processing apparatus 140 to which the position
sensor body 131 controls the position sensor body 131
25 through a position/direction acquisition thread in thread
S311 in Fig. 3 to acquire measurement values. This
processing apparatus 140 then accesses the network 150 to

distribute the measurement values obtained by the respective position sensors to the other processing apparatus.

The processing apparatus 140 to which the position
5 sensor body 131 is not connected accesses the network
through a position/direction acquisition thread in thread
S311 in Fig. 3 to acquire the measurement values obtained
by the respective position sensors which are sent from the
processing apparatus 140 to which the position sensor body
10 131 is connected.

[Fourth Embodiment]

The fourth embodiment is obtained by developing the
first embodiment to have one each of a position sensor
15 transmitter and a position sensor body for one position
sensor. In this case, two components, i.e., a position
sensor transmitter and position sensor body, are required
for one position sensor, and hence the cost increases
accordingly. However, a viewpoint position, a
20 line-of-sight direction, and the position and direction of
the hand can be measured with high accuracy.

Fig. 12 is a view showing the schematic arrangement
of a mixed reality system to which the fourth embodiment
is applied. This system additionally has a hand position
25 sensor transmitter 160 and position sensor body 161 as
compared with the arrangement of the first embodiment shown
in Fig. 1. The hand position sensor body 161 is connected

to a processing apparatus 140, and the hand position sensor transmitter 160 is connected to the hand position sensor body 161. A hand position sensor 121 is designed to receive magnetism from the hand position sensor transmitter 160.

5 In this embodiment, a position sensor transmitter 130 and position sensor body 131 function as dedicated devices for the eyes.

The hand position sensor transmitter 160 is so placed as to shorten the distance between the hand position sensor 10 121 and the hand position sensor transmitter 160 at/in the hand position and direction where an observer observes the hand with a high frequency. The position sensor transmitter 130 is so placed as to shorten the distance between an eye position sensor 113 and the eye position 15 sensor transmitter 130.

Although the procedure executed by the processing apparatus 140 is almost the same as that in the first embodiment except that in thread S311 in Fig. 3, a position/direction acquisition thread controls the 20 plurality of position sensor bodies 131 and 161 to acquire measurement values from the respective sensor bodies.

By arranging the dedicated position sensor transmitter and position sensor body for each position sensor in this manner, positional shifts between a real 25 space picture and a virtual space picture can be further reduced in the viewpoint position, the line-of-sight direction, and the hand position and direction where the

hand is observed with high frequencies, as compared with the second embodiment. This allows the observer to observe a mixed real space picture with higher quality.

The fourth embodiment is especially effective in preventing an observer from feeling a positional shift when a translucent virtual space object like seawater or a virtual space picture almost equal in size to a hand (real space picture) is to be expressed as if it were always on the hand of the observer.

10 Assume that a virtual space object is not translucent. In this case, if the virtual space object is larger than the hand, the hand is completely hidden by the virtual space object. Even if, therefore, a slight positional shift occurs, the resultant mixed real space picture does not look
15 strange to the observer. In the case of a translucent virtual space object equal in size to a hand, even with a slight positional shift, the hand cannot be hidden by the virtual space object, and the positional shift between the hand and the virtual space object is seen by the observer.
20 Furthermore, in the case of a translucent virtual space object, a positional shift between a virtual space object and a real space object is always seen by the observer regardless of the size of the virtual space object.

Even in such a situation, this embodiment can prevent
25 the observer from observing positional shifts between the virtual space object and the real space object.

Note that the quality of a mixed real space picture

can be improved by placing the eye position sensor transmitter 130 above the head of the observer, as shown in Fig. 13, as in the first embodiment. In addition, if possible, the hand position sensor transmitter 160 may be
5 placed below the hand position at/in the hand position and direction where the observer uses the system with a high accuracy. With this arrangement, the hand position sensor transmitter 160 does not interfere with the field of view of the observer in the horizontal direction, thereby
10 presenting a mixed real space picture with higher quality.

[Fifth Embodiment]

Fig. 14 is a view showing the arrangement of a mixed reality system to which the fifth embodiment is applied.
15 In this embodiment, as in the fourth embodiment, position sensor transmitters 130 and 160 and position sensor bodies 131 and 161 are respectively provided for an eye position sensor 113 and hand position sensor 121 to allow high-accuracy measurement of a viewpoint position, a
20 line-of-sight direction, and the position and direction of the hand. In addition, the position sensor transmitters 130 and 160 and position sensor bodies 131 and 161 are shared by two observers to attain a reduction in cost.

The two position sensor bodies 131 and 161 are
25 connected to only one processing apparatus 140 and are not connected to the other processing apparatus 140. The processing apparatuses 140 for the respective observers are

therefore connected to each other through a network 150 to allow the processing apparatus 140 to which the position sensor bodies 131 and 161 are not connected to create a mixed real space picture.

5 In this embodiment, as shown in Fig. 15, the distance between the eye position sensor 113 for each observer and the eye position sensor transmitter 130 and the distance between the hand position sensor 121 and the hand position sensor transmitter 160 are minimized at a position where
10 each observer makes observations with a high frequency. In addition, the eye position sensor transmitter 130 and hand position sensor transmitter 160 are placed such that the distances between the eye position sensors 113 for the respective observers and the position sensor transmitter
15 130 become almost equal to each other, and the distances between the hand position sensors 121 for the respective observers and the hand position sensor transmitter 160 become almost equal to each other.

With this arrangement, all observers can observe a
20 high-quality mixed real picture with positional shifts between a virtual object and a real object being further reduced, and positional shifts are made uniform to all the observers.

The procedure executed by each processing apparatus
25 140 is the same as that in the first embodiment except that the processing apparatus 140 to which the position sensor bodies 131 and 161 are connected controls the position

sensor bodies 131 and 161 through a position/direction acquisition thread in thread S311 in Fig. 3 to acquire measurement values. The apparatus then accesses the network 150 to distribute the measurement values obtained
5 by the respective position sensors to the other processing apparatus.

If the eye position sensor transmitter 130 is placed above the head of an observer and the hand position sensor transmitter 160 is placed below the hand position where the
10 observer observes the hand with a high frequency as in the fourth embodiment, the position sensor transmitters 130 and 160 do not interfere with the field of view of the observer in the horizontal direction. This allows the observer to observe a high-quality mixed real space picture in the
15 direction in which a mixed real space is observed with a high frequency.

[Sixth Embodiment]

Fig. 16 is a view showing the schematic arrangement
20 of a mixed reality system to which the sixth embodiment is applied. Referring to Fig. 16, reference numerals 300a and 300b denote observers who observe mixed real space pictures created in this system. Each of the observers 300a and 300b wears an HMD 301 on which a receiver 302 is mounted.
25 Each observer can observe a mixed real space corresponding to position/direction measurement values through the HMD 301.

Reference numeral 306 denotes a position/direction measurement apparatus. A transmitter 304 and receiver 302 are connected to this position/direction measurement apparatus 306. The magnetism generated from the transmitter 304 is received by the receiver 302. The position/direction measurement apparatus 306 then measures the viewpoint position and line-of-sight direction of the observer from the strength of magnetism.

The position/direction measurement apparatus 306 is connected to a processing apparatus 307 to be always notified of the viewpoint position and line-of-sight direction of the observer from the position/direction measurement apparatus 306. The processing apparatus 307 creates a mixed real space picture corresponding to the viewpoint position and line-of-sight direction of each observer on the basis of this information, and displays it on the HMD 301.

The processing apparatuses 307 for the respective observers are connected to each other through a network 330. The respective processing apparatuses 307 share the viewpoint positions and line-of-sight directions of the respective observers and the position and direction of a virtual space object by using the network 330. This allows a given observer to display a virtual space object at the position of the other observer.

Figs. 17 and 18 are perspective views of the HMD 301 to which the sixth embodiment is applied. Fig. 17 is a

perspective view from the direction of a photographing unit.
Fig. 18 is a perspective view from the direction of a display unit.

Reference numeral 201 denotes an HMD display unit.

5 This HMD display unit 201 includes two units, i.e., a right-eye display 201R and left-eye display 201L, each of which has a color liquid crystal and prism. A mixed real space picture corresponding to the viewpoint position and line-of-sight direction of an observer is displayed on each
10 display unit.

Reference numerals 204 to 208 denote constituent members for head mounting. To mount the HMD 301 on the head, the observer wears it while the length adjusting portion 206 is loosened by the adjuster 205. After the forehead
15 pad 208 is brought into tight contact with the forehead, the length adjusting portion 206 may be fastened by the adjuster 205 to bring the temple bridges 204 and occiput pad 207 into tight contact with the temple and occipital portion of the observer, respectively.

20 Reference numeral 203 denotes an HMD photographing unit for photographing a real space picture at/in the viewpoint position and line-of-sight direction of an observer. This HMD photographing unit 203 includes two units, i.e., a right-eye photographing unit 203R and
25 left-eye photographing unit 203L, each of which is formed by an NTSC compact video camera. The photographed real space picture is superimposed on a virtual space picture

to create a mixed real space picture.

The receiver 302 is used to receive magnetism generated by the transmitter 304 as information for the measurement of the viewpoint position and line-of-sight direction of the observer. As the mount portions of the receiver 302 for the HMD 301, three portions, i.e., receiver joints 200R, 200L, and 200C, are formed. The receiver 302 can be detachably mounted on an arbitrary joint of these receiver joints 200R, 200L, and 200C. Referring to Figs. 17 and 18, the receiver 302 is mounted on the receiver joint 200R on the right side in the direction of the light of sight of the observer. However, the receiver 302 can be amounted on the receiver joint 200L on the left side in the direction of the light of sight of the observer or the receiver joint 200C on the median line of the observer.

In this embodiment, the receiver joints 200R, 200L, and 200C are designed to have receptacles in which the receiver 302 is fitted to be fixed. However, other detachable joint (mount) schemes may be used.

Reference numeral 210 denotes a receiver signal line, which is exposed outside the HMD 301 at a position near the receiver joint 200C. This receiver signal line 210 is long enough to allow the receiver 302 to be mounted on either of the receiver joints 200R, 200L, and 200C.

Reference numeral 209 denotes a tied linear member obtained by binding various kinds of lines, e.g., signal lines and power feed lines to the HMD photographing unit

203 and the like and the above receiver signal line 210. The tied linear member 209 is attached to the occipital portion mount portion 207. Signal lines and power feed lines to the right and left displays 201R and 201L, HMD
5 photographing units 203R and 203L, and the like in the tied linear member 209 pass through the right and left temple mount portions 204.

Fig. 19 is a block diagram showing a hardware arrangement corresponding to one observer in the system
10 shown in Fig. 16. The processing apparatus 307 incorporates a right-eye video capture board 350, left-eye video capture board 351, right-eye graphic board 352, left-eye graphic board 353, I/O interface 354, and network interface 359. These constituent elements are connected
15 to a CPU 356, HDD 355, and memory 357.

The left- and right-eye video capture boards 351 and 350 are respectively connected to the left- and right-eye video cameras 203L and 203R, and convert pictures actually photographed by these video cameras 203L and 203R into
20 pictures in a form that can be processed by the processing apparatus 307 with a virtual space picture. The left- and right-eye graphic boards 353 and 352 are respectively connected to the left- and right-eye display units (devices) 201L and 201R to perform display control on the
25 left- and right-eye display units 201L and 201R.

The I/O interface 354 is connected to the position/direction measurement apparatus 306. The

network interface 359 is connected to the network 330. Note that each of the processing apparatuses 140 according to the first to fifth embodiments is constituted by the same constituent elements as those of the processing apparatus 5 307 according to this embodiment.

An outline of processing performed by the mixed reality system according to this embodiment will be described next. In this system, (1) a real space picture at/in the current viewpoint position and line-of-sight 10 direction of an observer is acquired, (2) the viewpoint position and line-of-sight direction of the observer are acquired, and (3) a virtual space picture at/in the acquired viewpoint position and line-of-sight direction is created. In this case, the positional relationship between an object 15 in a virtual space viewed from the viewpoint position and an object in a real space in consideration of the position, shape, and the like of the object in the real space which are stored in advance, (4) the real space picture is superimposed on the virtual space picture to create a mixed 20 real space picture, and (5) the mixed real space picture is presented to the observer. By repeating this series of operations, the observer is made to experience a mixed real space picture.

In this series of operations, acquisition processing 25 of a real space picture at/in the current viewpoint position and line-of-sight direction of the observer is performed by the video capture boards 350 and 351. More specifically,

the video capture boards 350 and 351 convert video signals from the video cameras 203R and 203L into digital signals and continuously store them in the memory 357. The viewpoint position and line-of-sight direction of the observer are kept transmitted from the position/direction measurement apparatus 306 to the processing apparatus 307 through the I/O interface 354.

The processing apparatus 307 updates the time in a virtual space on the basis of a program stored in the memory 357 and calculates the position and direction of the virtual space object again. A virtual space picture corresponding to the viewpoint position and direction of the observer, which are acquired through the I/O interface 354, is created.

In this case, by defining in advance an object existing in a real space such that it exists in a virtual space, a virtual space picture can also be created in consideration of the positional relationship between the real space object and the virtual space object. For example, a virtual space object can be seen as if it were hidden behind a real wall.

Finally, the real space picture and virtual space picture created in the memory 357 are superimposed on each other to create a mixed real space picture. The created mixed real space picture is displayed on the HMD displays 201R and 201L under the control of the graphic boards 352 and 353.

A method of mounting the receiver 302, which is a characteristic feature of this embodiment, will be described next. Fig. 20 shows a state where the receiver 302 is mounted on a right receiver joint 210R of the HMD 301 for the observer 300a, and the receiver 302 is mounted on left receiver joint 210L of the HMD 301 for the observer 300b in the same situation as that shown in Fig. 22 which shows the problem in the prior art.

Assume that the transmitters 304 for measuring the viewpoint positions and line-of-sight directions of the observers 300a and 300b are placed at the positions in Fig. 20. In this case, by selecting receiver joints for mounting the receivers 302 in the above manner, the distances between the transmitters 304 and receivers 302 used by the observers 300a and 300b are shortened when both the observers 300a and 300b set their viewpoint positions in movable areas 311, and line-of-sight directions are set in the direction of a mixed real space picture observable area 312. In other words, position/direction measurement errors can be reduced in a situation where the observers 300a and 300b make observations with high frequencies.

In addition, by selecting mount positions for the receivers 302 as shown in Fig. 20, since the observers 300a and 300b, receivers 302, and transmitters 304 are symmetrical about a line segment 313 passing through the center of the mixed real space picture observable area 312, measurement errors of positions and directions associated

with the two observers 300a and 300b can be made uniform.

[Seventh Embodiment]

The seventh embodiment is applied to a case where
5 transmitters 304 are placed in front of observers 300a and
300b, as shown in Fig. 21.

When the transmitters 304 are placed in front of the
observers 300a and 300b in this manner, receivers 302 are
mounted on central receiver joints 200C of HMDs 301 to
10 minimize the distances between the receivers 302 on the HMD
301 and the transmitters 304.

In this case, as in the sixth embodiment,
position/direction measurement errors can be reduced in a
situation where the observers 300a and 300b make
15 observations with high frequencies. In addition,
position/direction measurement errors associated with the
two observers 300a and 300b can be made uniform.

As described above, according to the first to seventh
embodiments positional shifts between a real space picture
20 and a virtual space picture can be reduced by the method
requiring no cost, i.e., adjusting the mount position of
the transmitter for position/direction measurement or the
mount position of the receiver on each HMD.

The present invention is not limited to the above
25 embodiments. For example, as the transmitters and
receivers (position/direction measurement apparatus), for
example, devices based on an ultrasonic scheme instead of

a magnetic scheme can be used. In addition, the respective embodiments described above can be properly combined with each other.

As has been described above, according to the present
5 invention, positional shifts between a real space picture and a virtual space picture can be reduced with an inexpensive arrangement.

Furthermore, the present invention can be applied to the system comprising either a plurality of units or a single
10 unit. It is needless to say that the present invention can be applied to the case which can be attained by supplying programs which execute the process defined by the present system or invention.

CLAIMS

1. A mixed reality system which creates and displays a mixed real space picture by combining a real space picture with a virtual space picture, characterized by comprising:
 - 5 a transmitter;
 - a first receiver which receives a signal generated by said transmitter to measure a viewpoint position and direction of an observer; and
 - a second receiver which receives a signal generated
 - 10 by said transmitter to measure a position and direction of another body region of the observer,
 - wherein said transmitter is positioned such that a distance between said transmitter and said first receiver becomes shorter than a distance between said transmitter
 - 15 and said second receiver.
2. The mixed reality system according to claim 1, characterized in that said transmitter is positioned such that the distance between said transmitter and said first receiver always become shorter than the distance between
- 20 said transmitter and said second receiver within at least a predetermined movement range of the observer.
3. The mixed reality system according to claim 1, characterized in that the mount position of said transmitter for measuring the viewpoint position and
- 25 direction of the observer is above the head of the observer.
4. The mixed reality system according to claim 1, characterized in that said transmitter is shared by said

plurality of first and second receivers.

5. The mixed reality system according to claim 1, characterized in that said receiver and transmitter receive and transmit magnetism or an ultrasonic wave.

5 6. A head mounted display apparatus which is used in a mixed reality system that creates and displays a mixed real space picture by combining a real space picture with a virtual space picture, and which can mount a receiver used to measure a viewpoint position and direction of an observer
10 to be mounted,

characterized in that a plurality of mount portions for detachably mounting said receiver are formed.

7. The head mounted display apparatus according to claim 6, characterized in that said mount portions are formed at
15 least on a median line of the observer and both left and right sides in a line-of-sight direction of the observer.

8. The head mounted display apparatus according to claim 6 or 7, characterized in that a signal line connected to said receiver extends from a portion near said mount portion
20 on the median line to the outside.

9. The head mounted display apparatus according to claim 6, characterized in that said receiver receives magnetism or an ultrasonic wave.

10. A method of positioning a transmitter in a mixed
25 reality system which includes the transmitter, a first receiver which receives a signal generated by the transmitter to measure a viewpoint position and direction

of an observer, and a second receiver which receives a signal generated by the transmitter to measure a position and direction of another body region of the observer, and creates and displays a mixed real space picture by combining
5 a real space picture with a virtual space picture,

characterized in that said transmitter is positioned such that a distance between the transmitter and the first receiver becomes shorter than a distance between the transmitter and the second receiver.

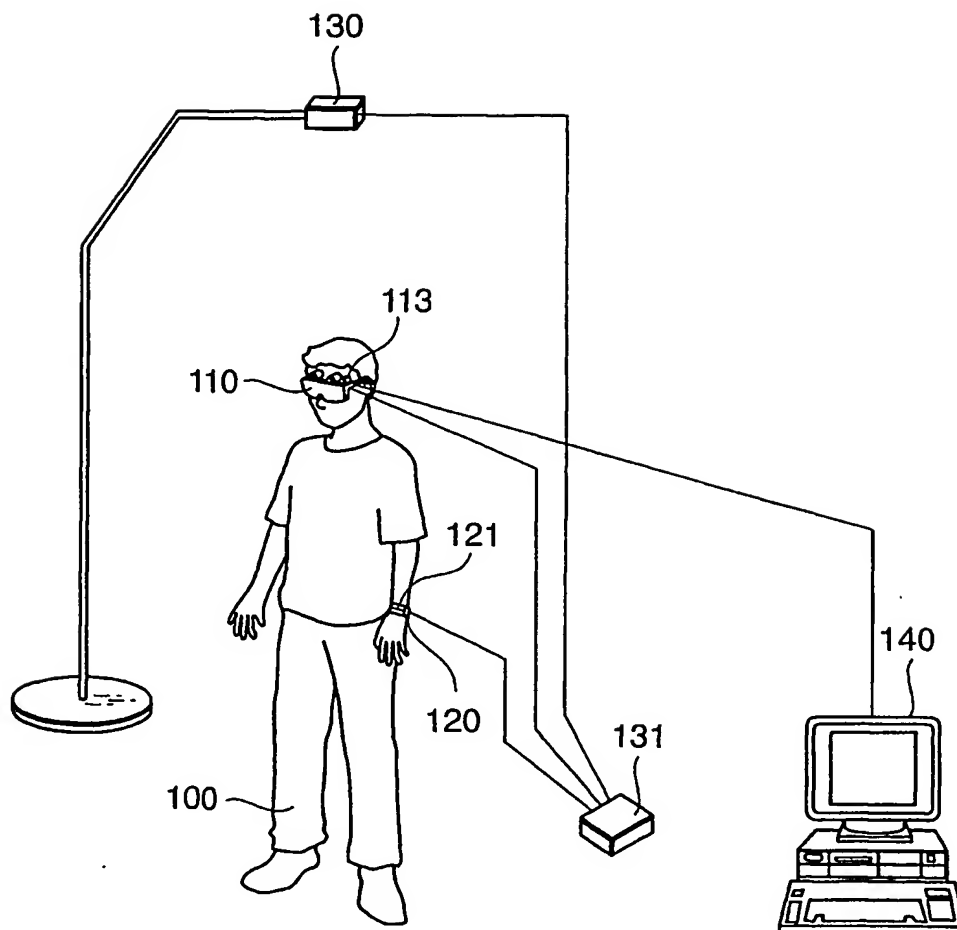
10 11. The method of positioning the transmitter in the mixed reality system according to claim 10, characterized in that said transmitter is positioned such that the distance between said transmitter and said first receiver always become shorter than the distance between said
15 transmitter and said second receiver within at least a predetermined movement range of the observer.

12. The method of positioning the transmitter in the mixed reality system according to claim 10, characterized in that the mount position of said transmitter for measuring
20 the viewpoint position and direction of the observer is above the head of the observer.

13. The method of positioning the transmitter in the mixed reality system according to claim 10, characterized in that said transmitter is shared by said plurality of
25 first and second receivers.

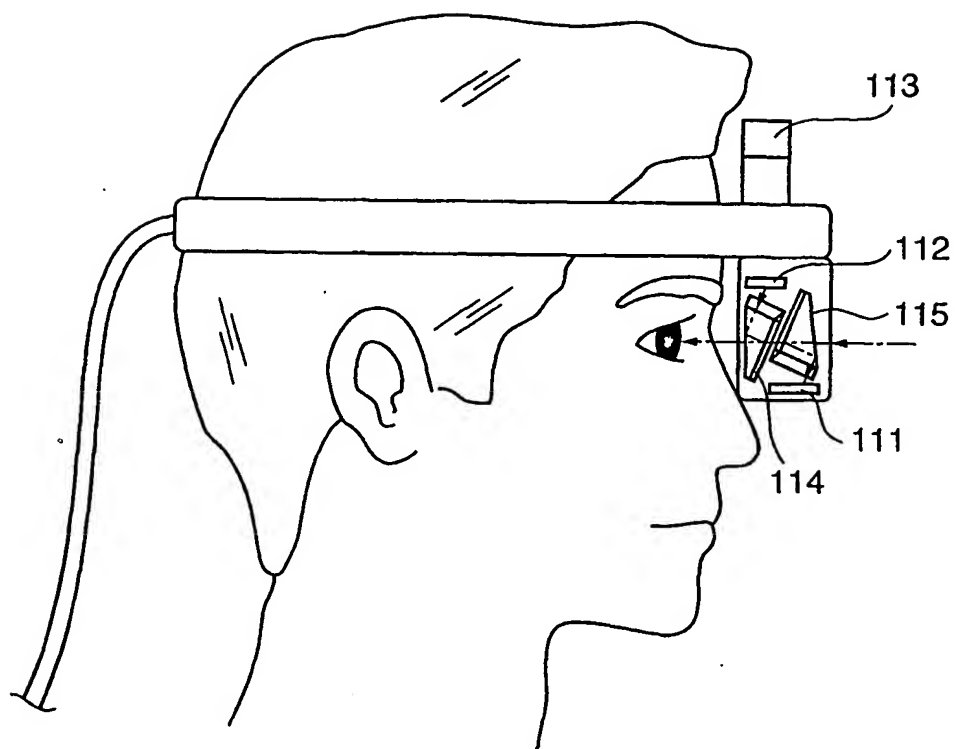
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FIG. 1



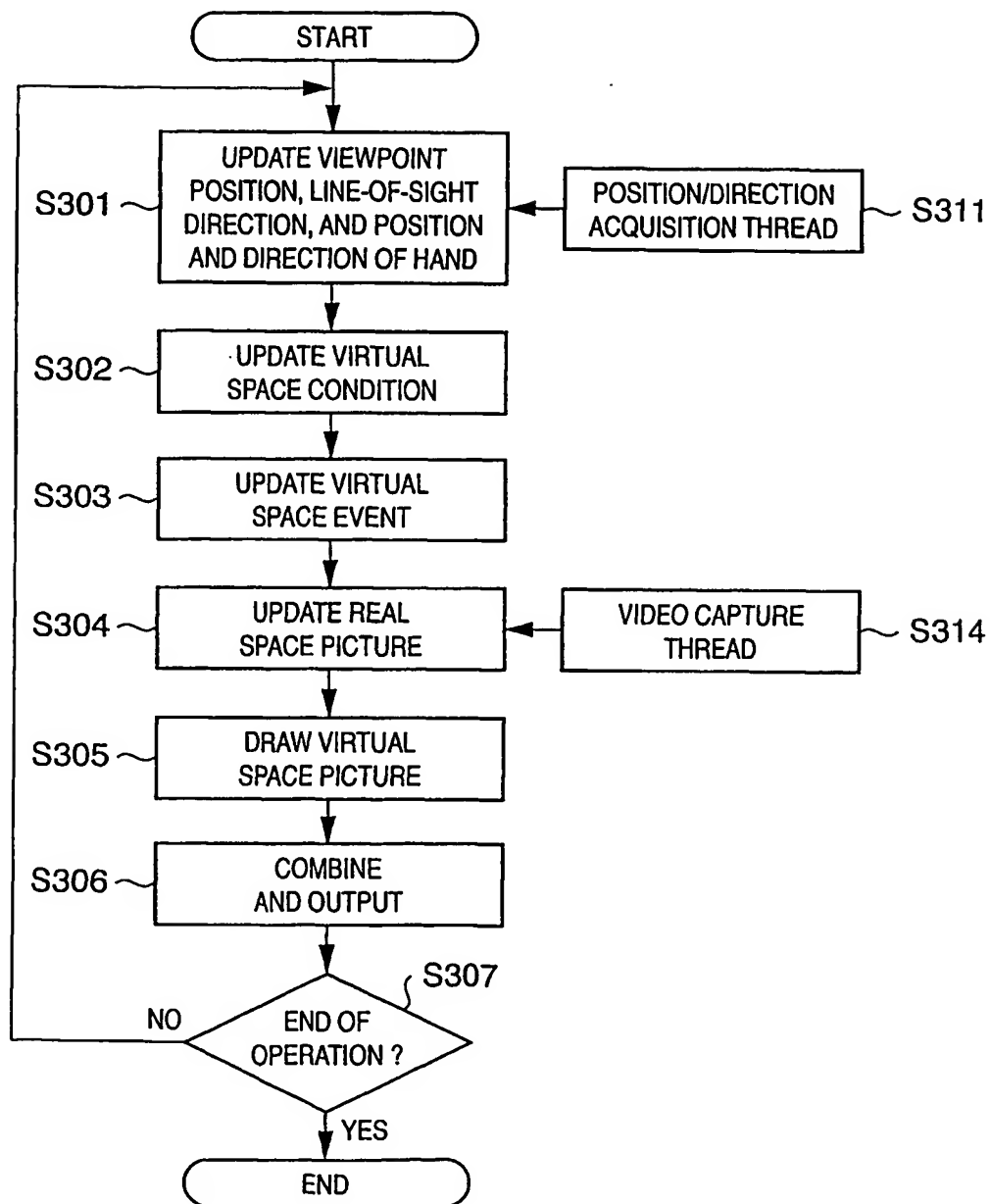
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FIG. 2



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FIG. 3



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FIG. 4A

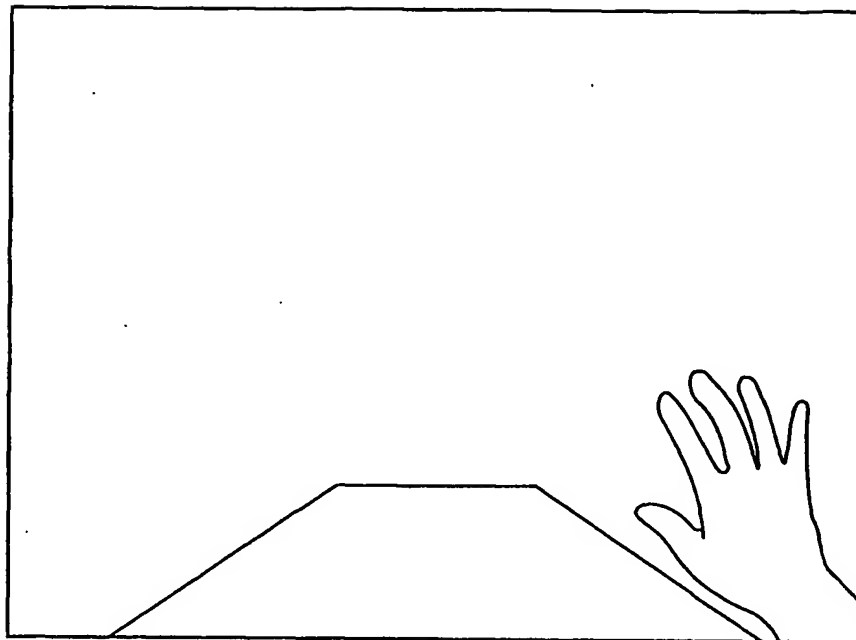
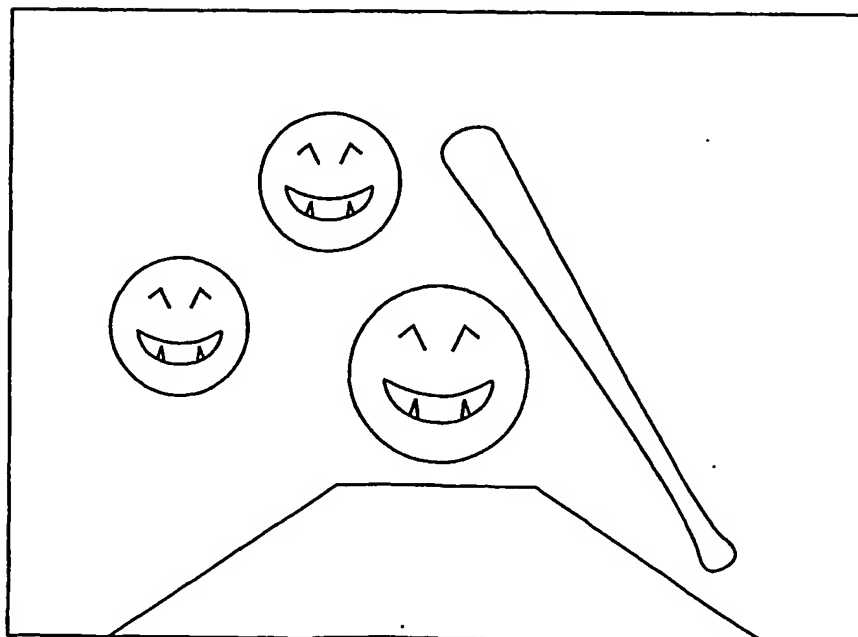
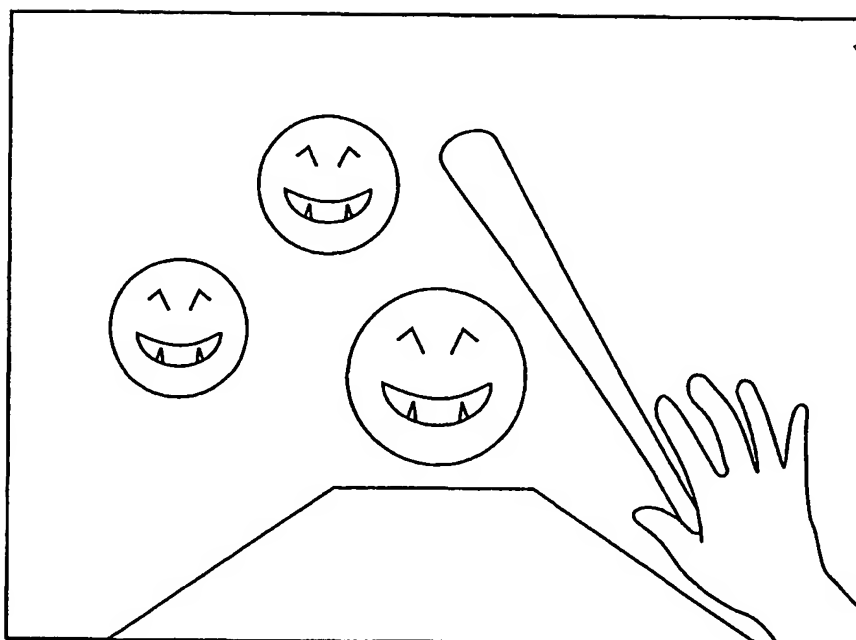


FIG. 4B



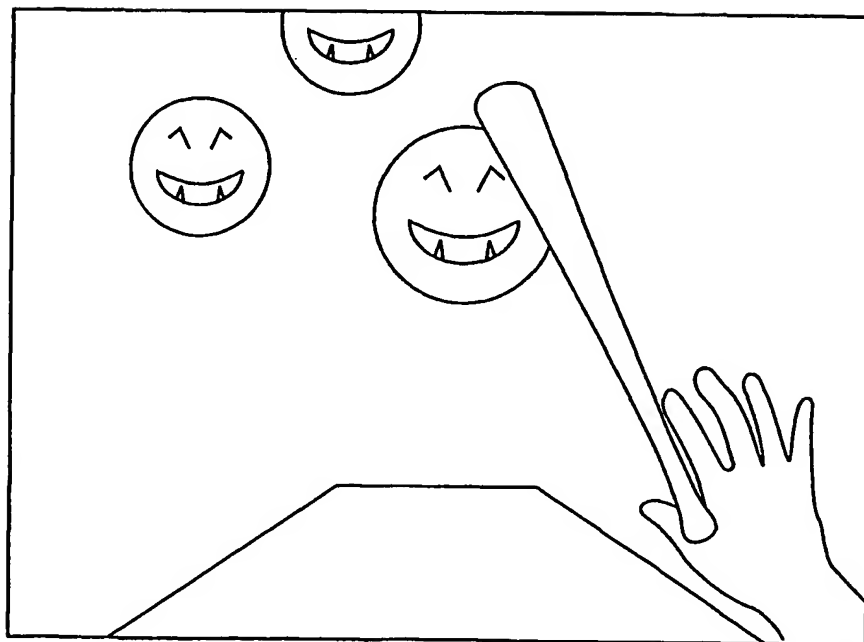
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FIG. 5



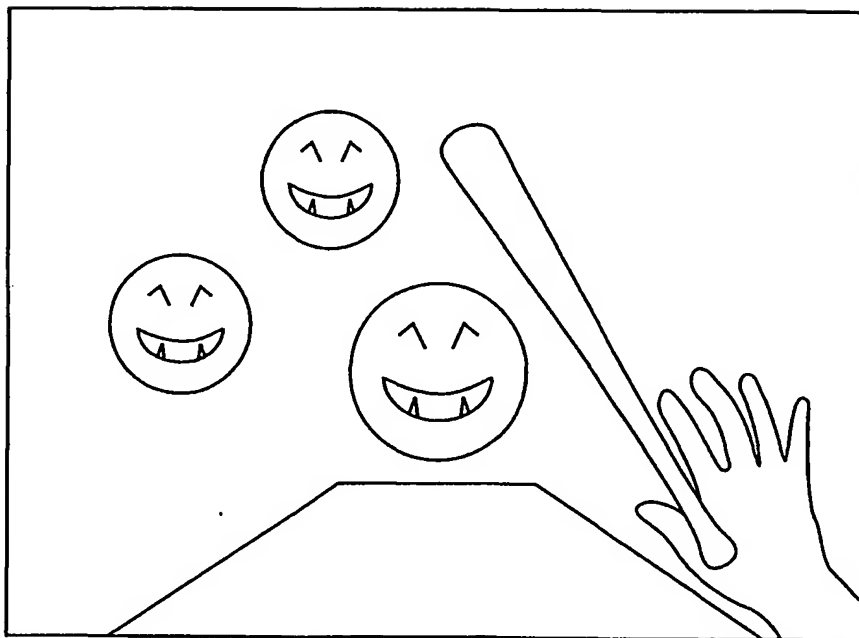
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FIG. 6



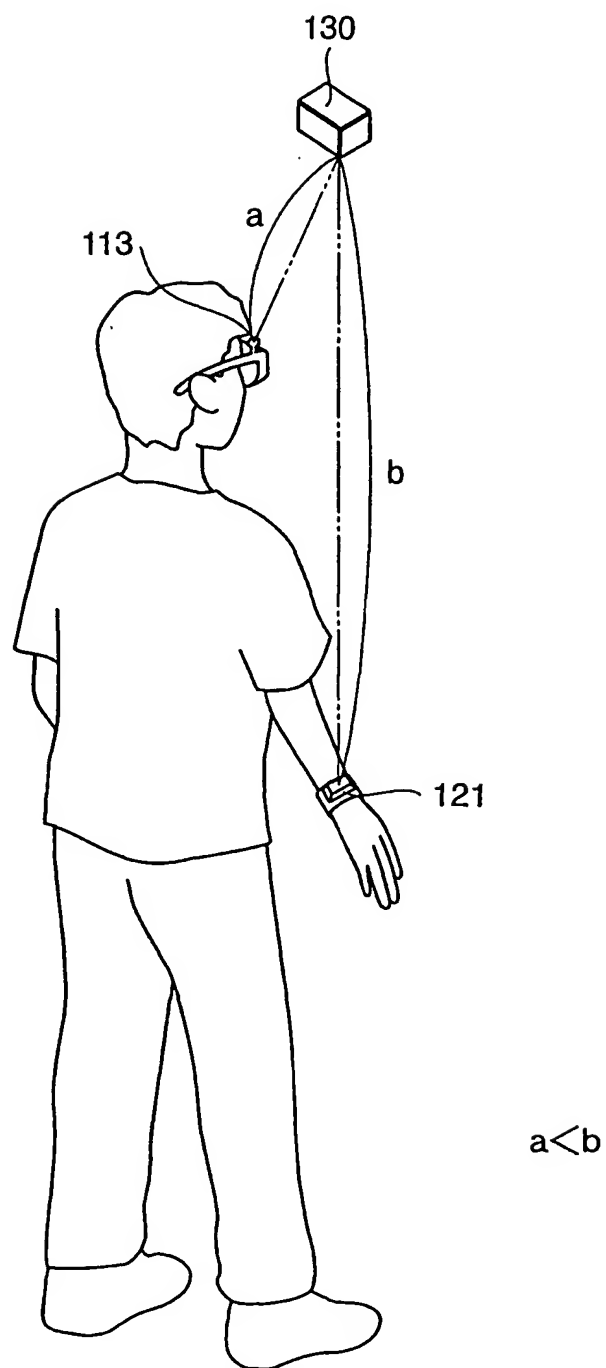
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FIG. 7



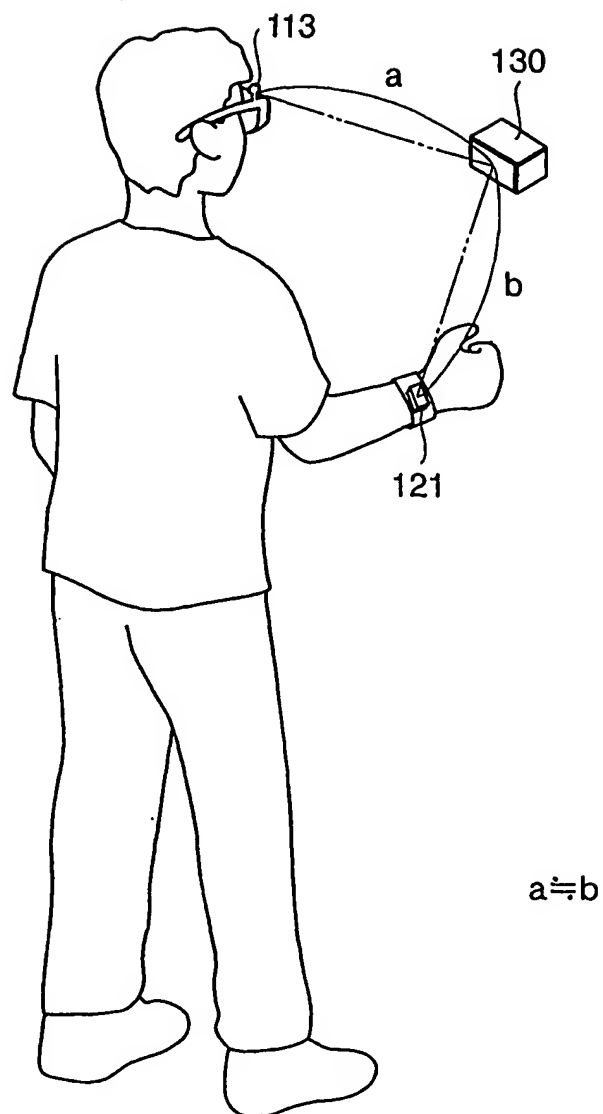
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FIG. 8



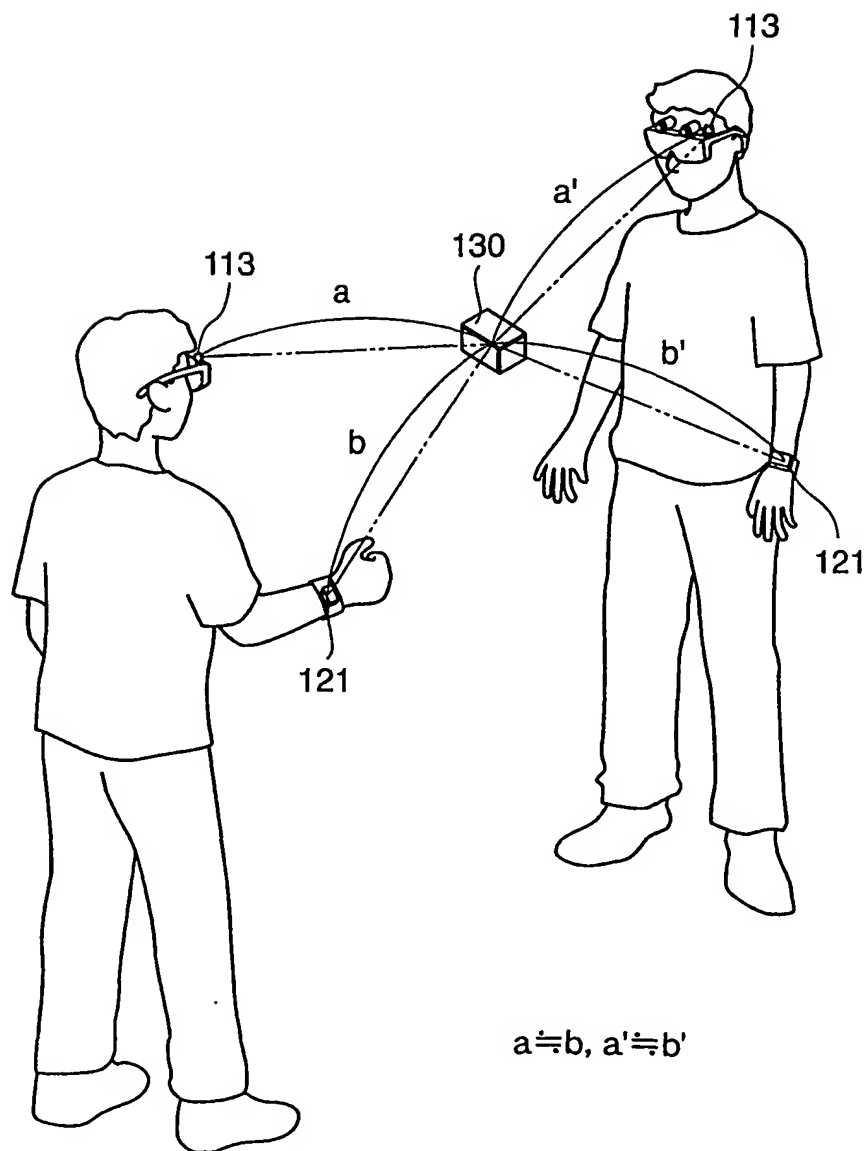
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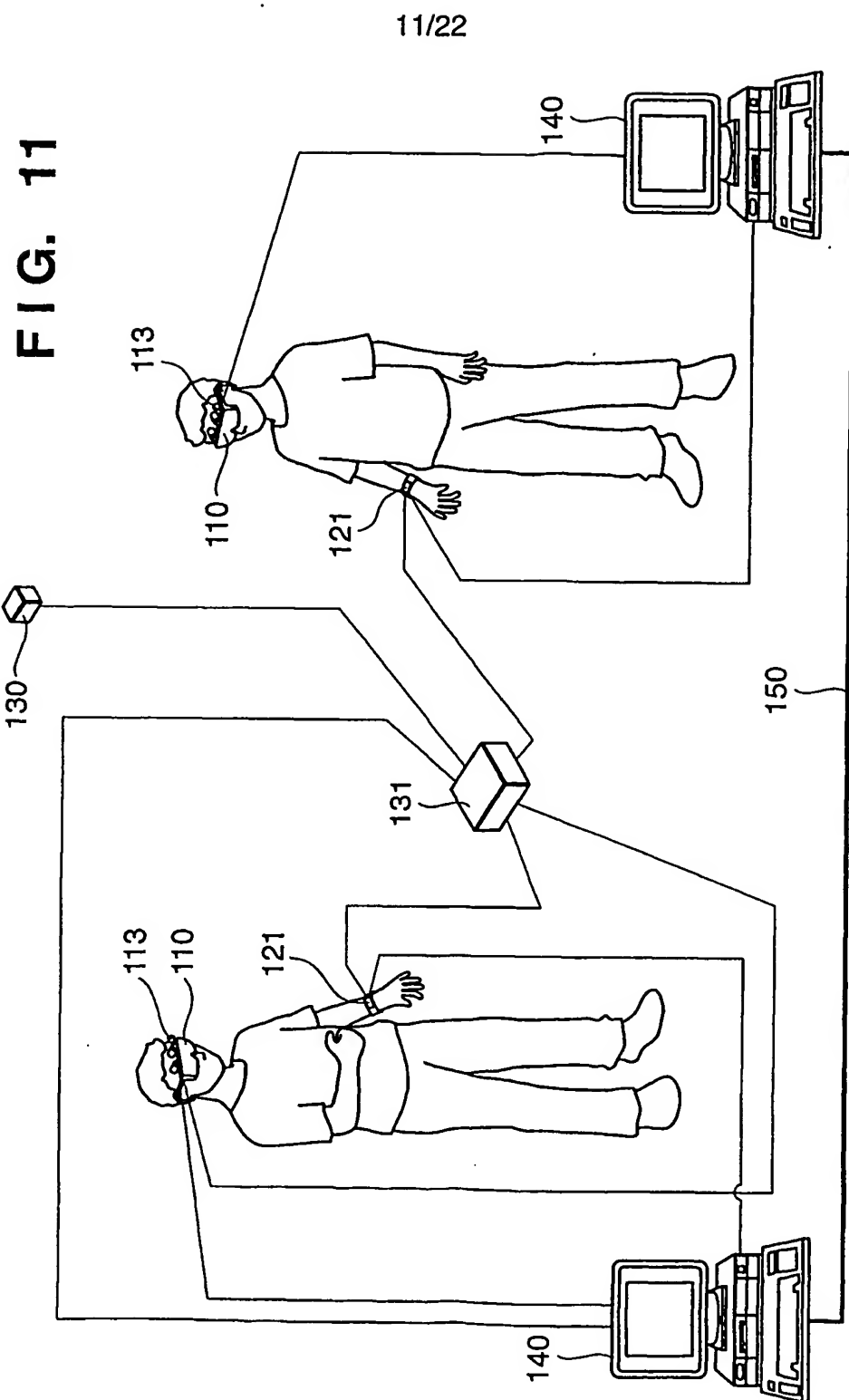
FIG. 9



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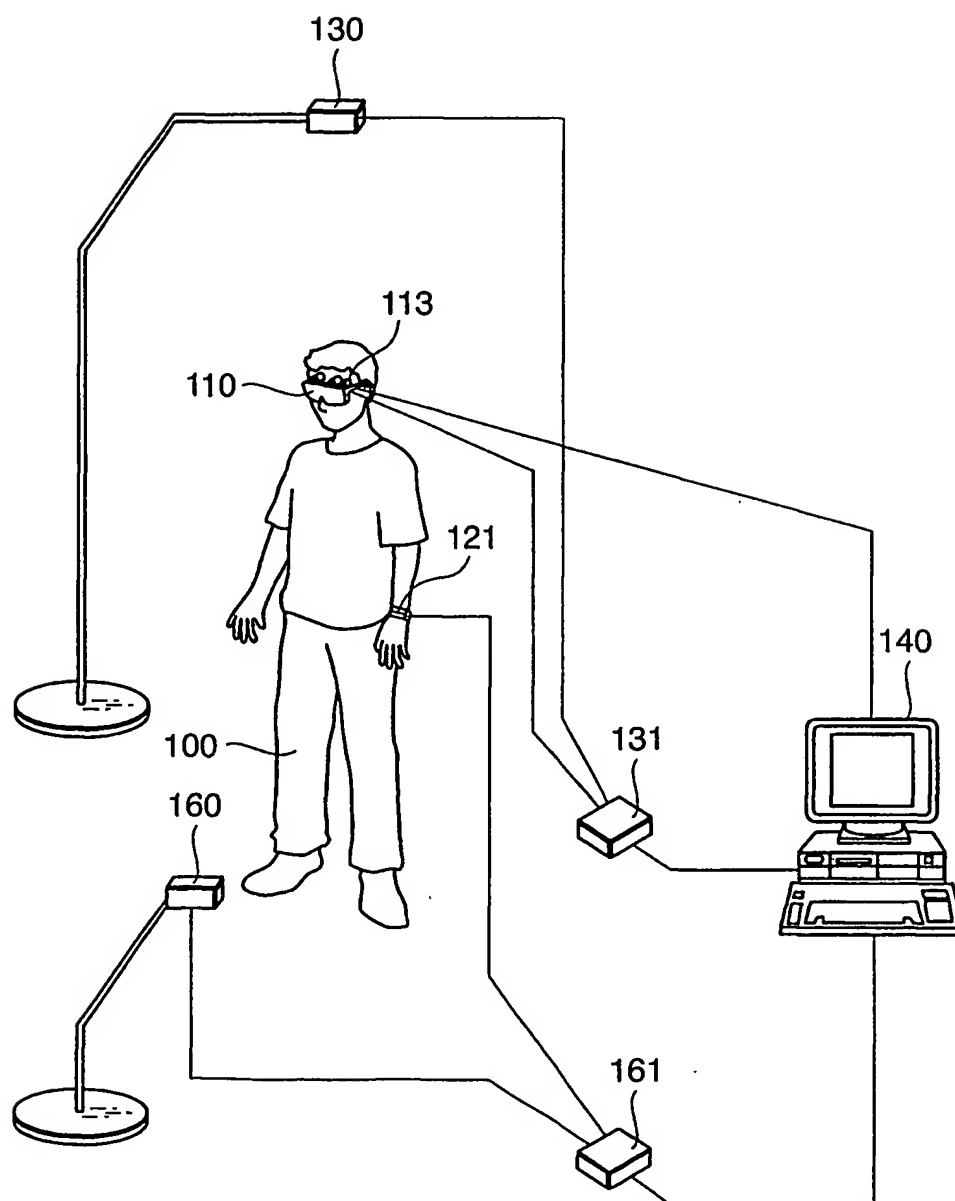
FIG. 10





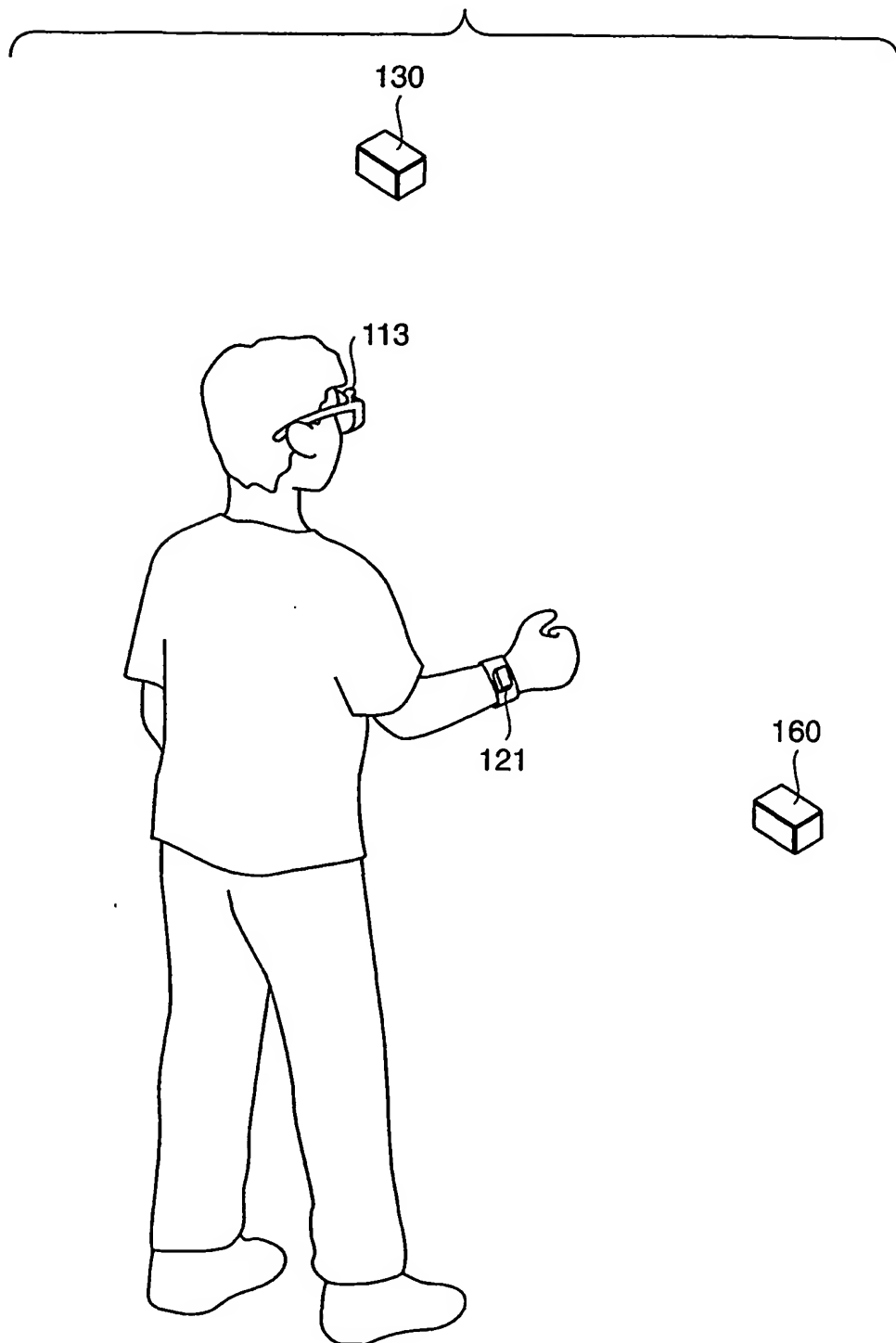
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FIG. 12

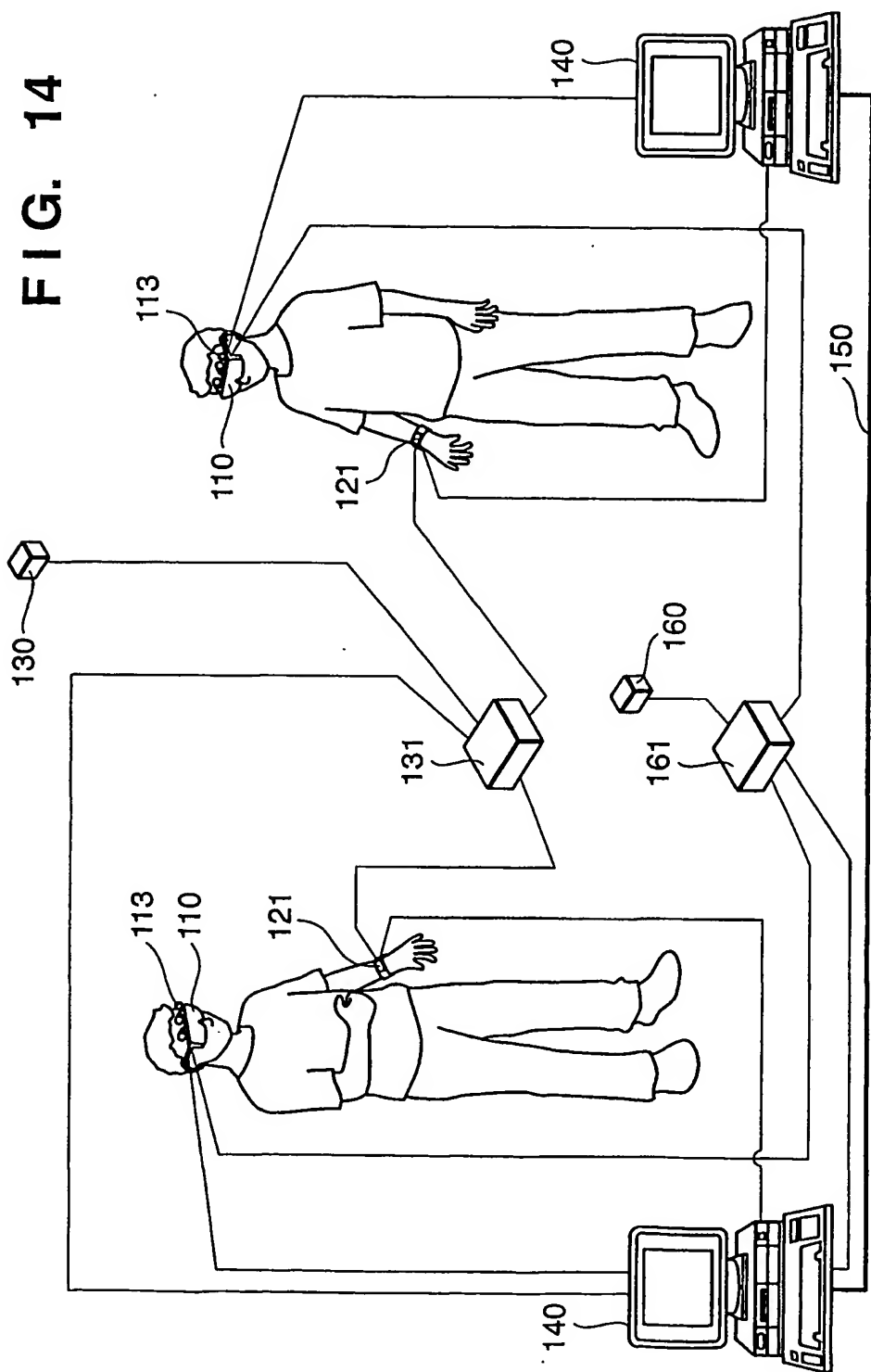


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FIG. 13



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FIG. 15

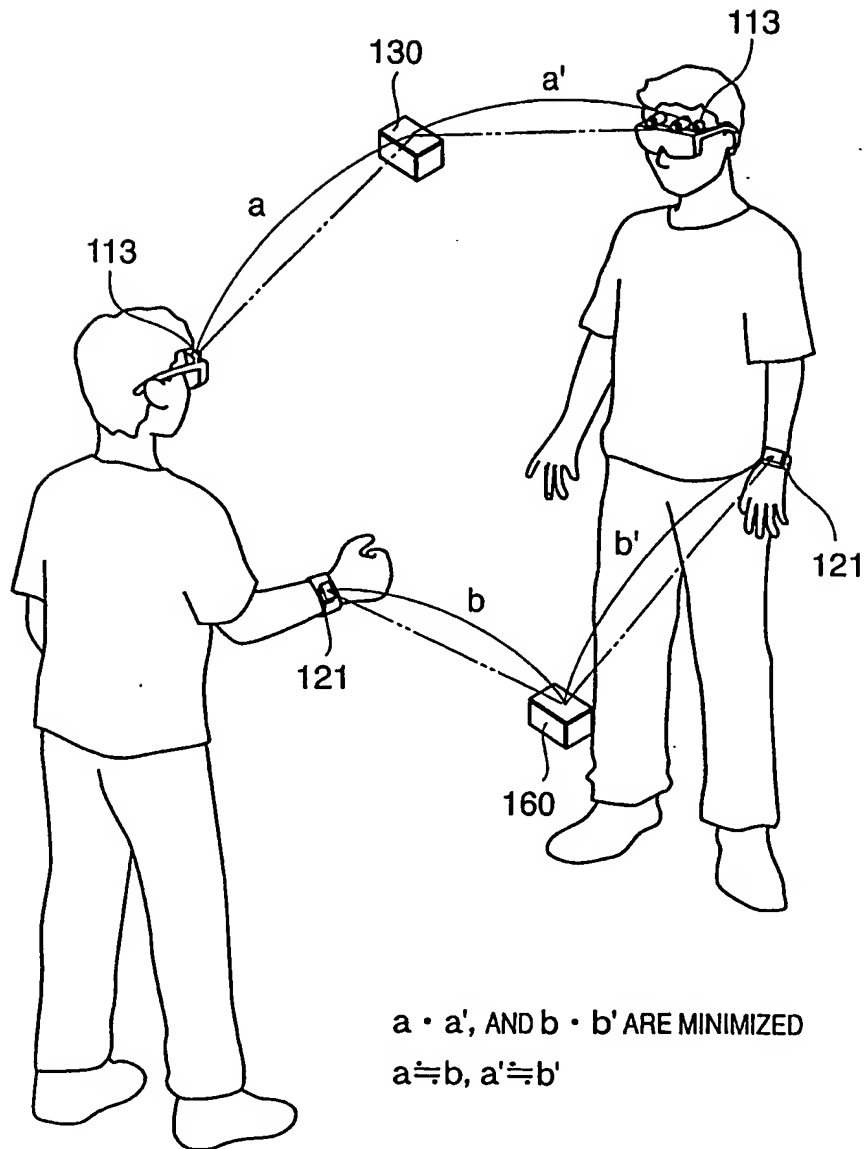
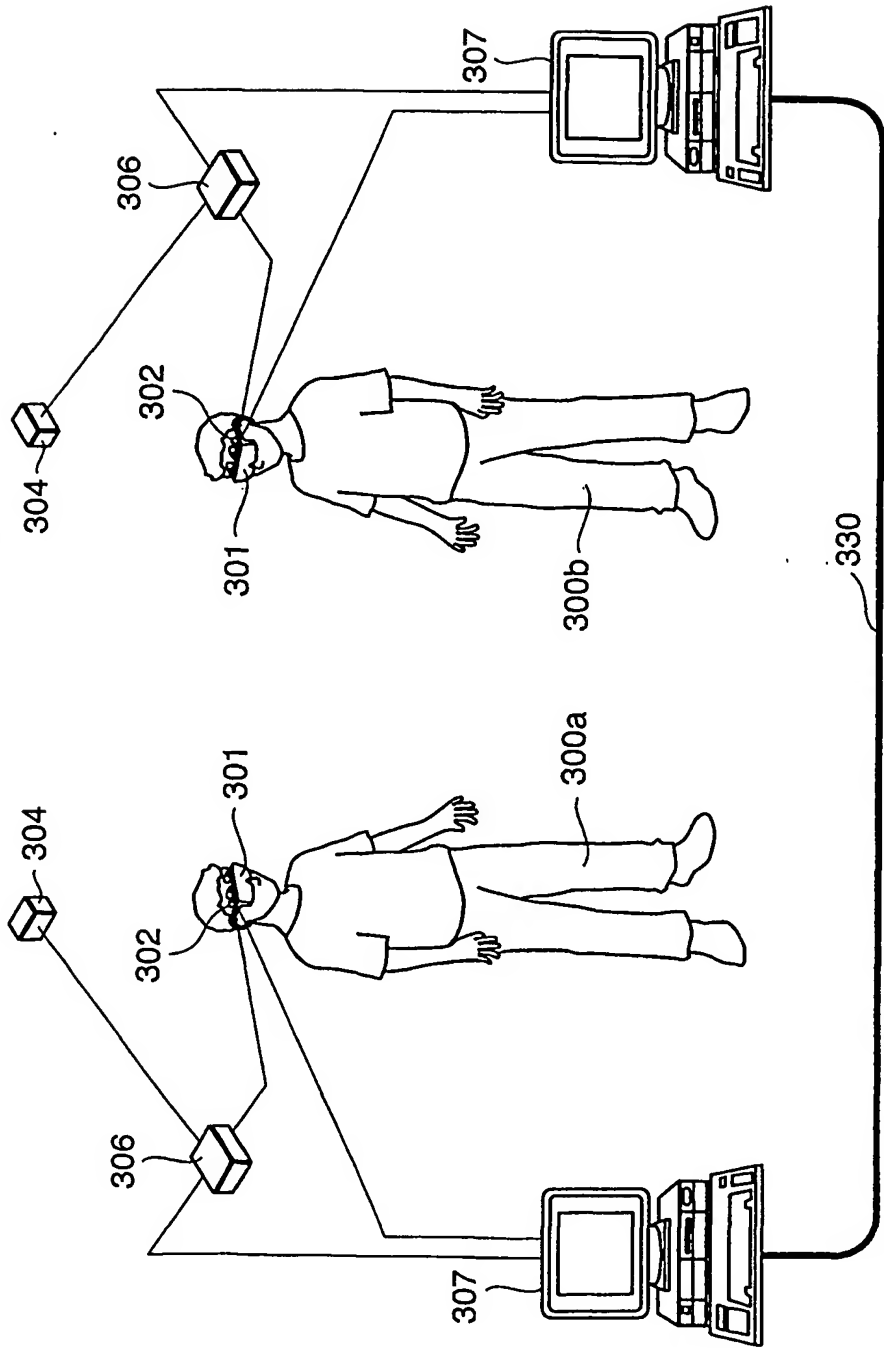
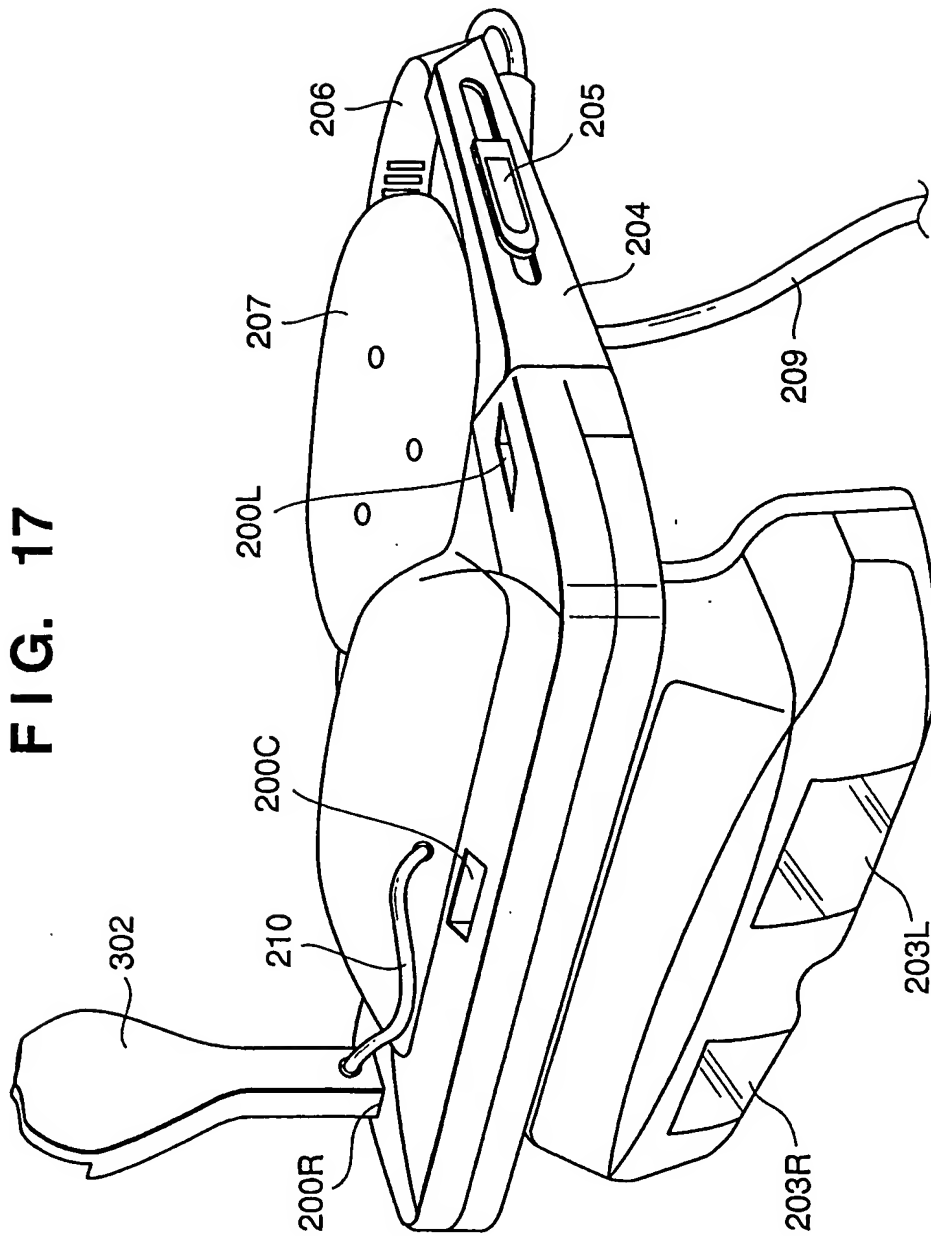


FIG. 16



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FIG. 17



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FIG. 18

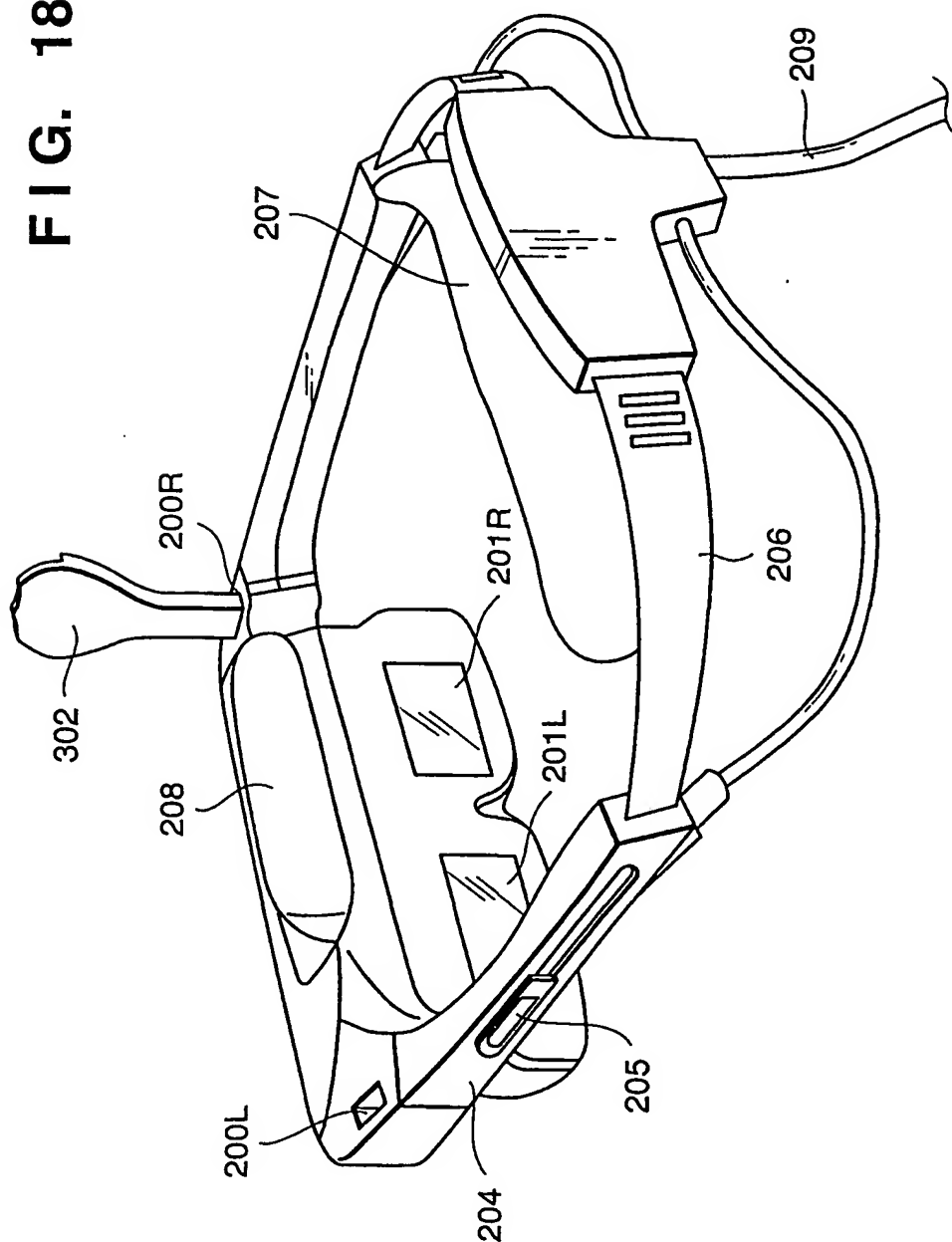
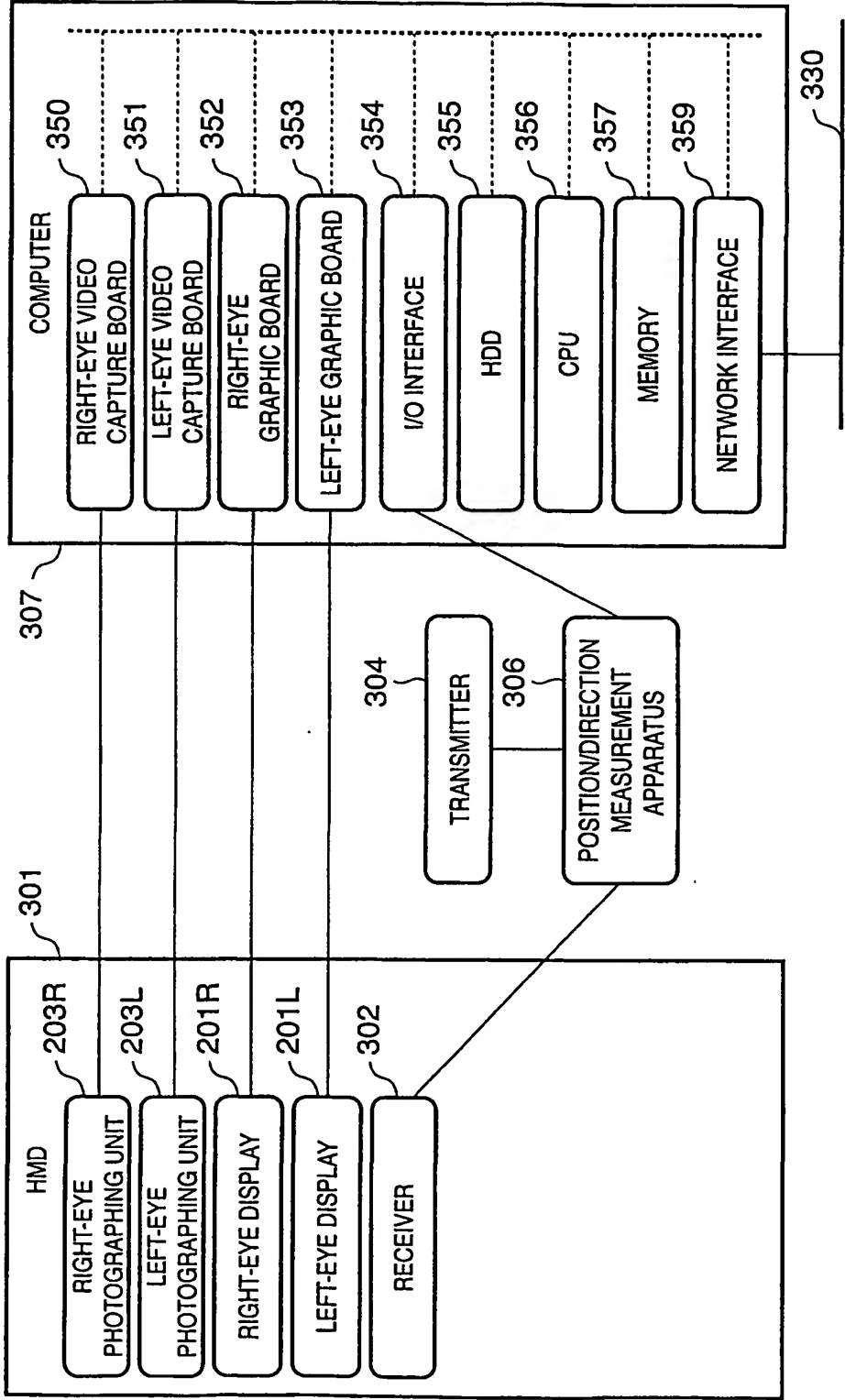
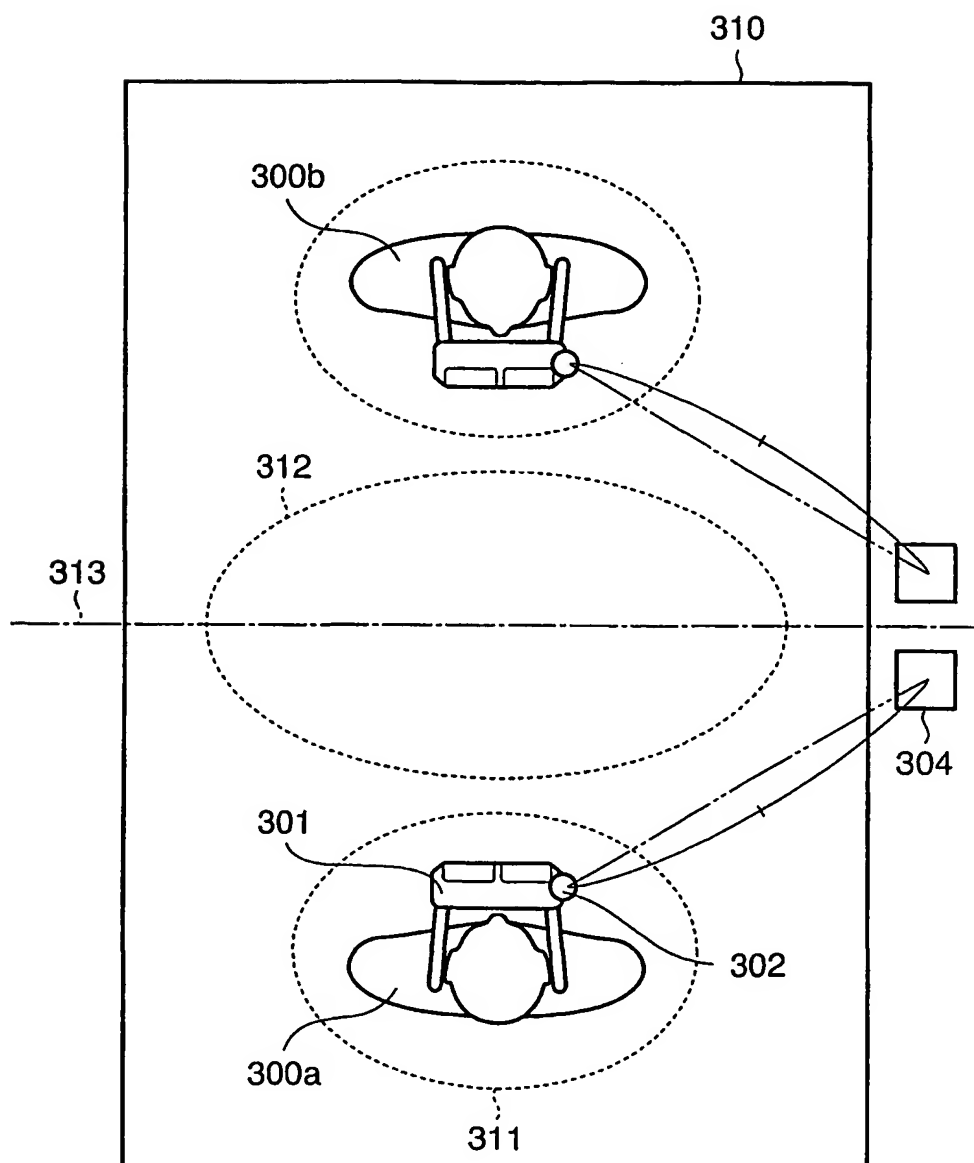


FIG. 19



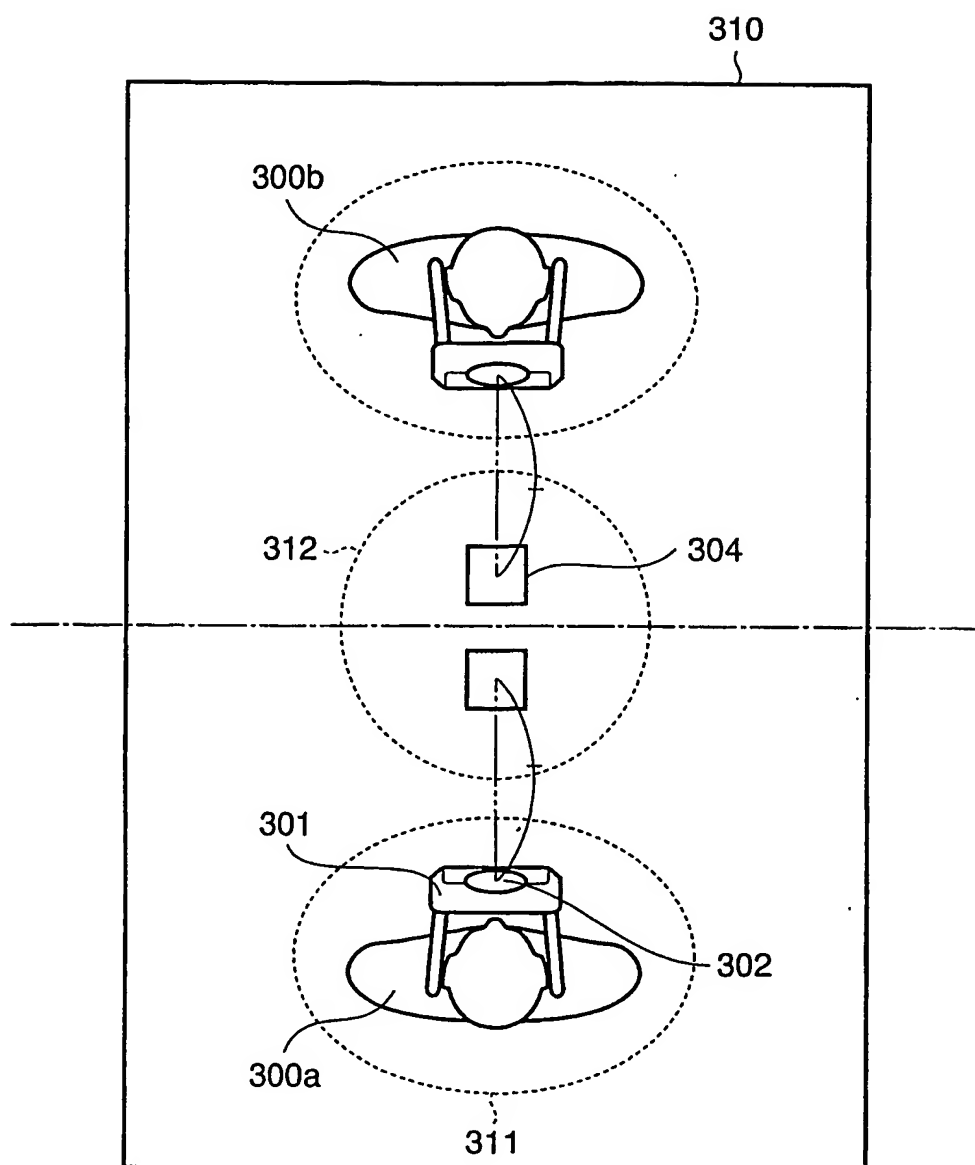
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FIG. 20



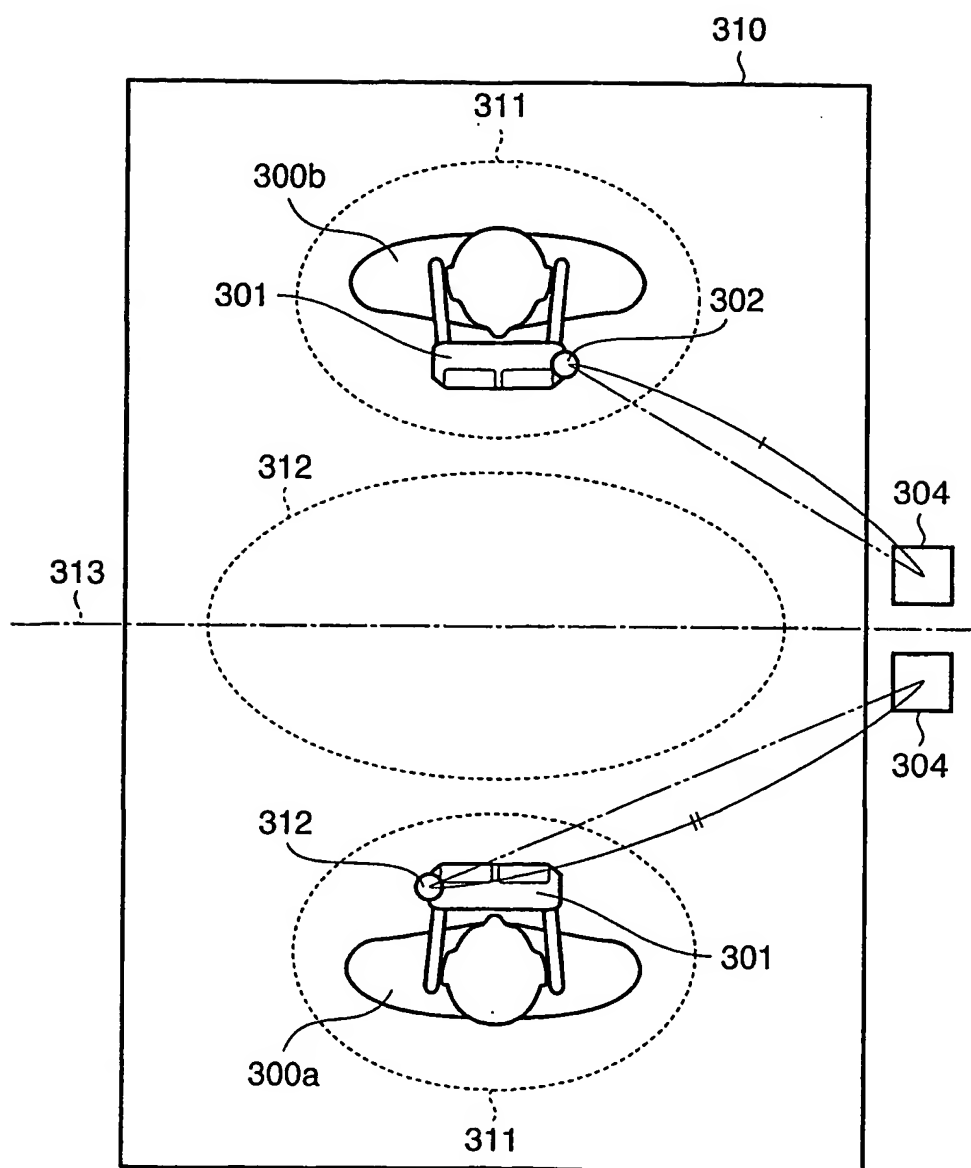
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FIG. 21



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FIG. 22



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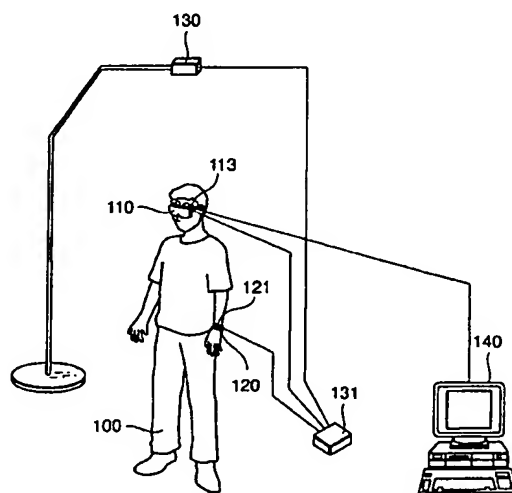
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(75) Inventors/Applicants (for US only): YONEZAWA, Hiroki [JP/JP]; 10-20-202, Ichibahigashinakacho, Tsurumi-ku, Yokohama-shi, Kanagawa 230-0022 (JP).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: MIXED REALITY SYSTEM WHICH REDUCES MEASUREMENT ERRORS OF VIEWPOINT POSITION AND DIRECTION OF AN OBSERVER



(57) Abstract: ABSTRACT A mixed reality system which reduces positional shifts between a real space picture and a virtual space picture with an inexpensive arrangement is disclosed. The mixed reality system according to this invention detects the viewpoint position and direction of an observer and the position and direction of another region of the observer by using reception results on signals output from a transmitter. In this mixed reality system, the transmitter is positioned such that the distance between the transmitter and a receiver used for the measurement of the viewpoint position and direction of the observer becomes shorter than the distance between the transmitter and a receiver used for the measurement of the position and direction of another region of the observer. This makes it possible to reduce measurement errors of the line-of-sight position and direction which are more dominant over positional shifts.

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/JP 02/02297

A. CLASSIFICATION OF SUBJECT MATTER

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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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IPC 7 G06F

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Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 060 772 A (MIXED REALITY SYSTEMS LAB INC) 20 December 2000 (2000-12-20) abstract; figure 1 paragraph [0016] paragraph [0050] - paragraph [0055] ---	1-13
A	JP 10 334275 A (CANON INC) 18 December 1998 (1998-12-18) paragraph [0068] - paragraph [0069]; figure 1 ---	1-13
A	US 6 005 548 A (LATYPOV NURULLA NURISLAMOVIKH ET AL) 21 December 1999 (1999-12-21) column 1, line 20 -column 6, line 22 --- -/--	1-13

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A	US 6 061 064 A (REICHLEN BRUCE A) 9 May 2000 (2000-05-09) column 2, line 35 -column 15, line 62; figure 1 -----	1-13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP 02/02297

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

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This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-5, 10-13

A mixed reality system in which a transmitter is positioned such that the distance to a receiver is short.

2. Claims: 6-9

A head mounted display apparatus which can mount a receiver on different receiver joints.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/JP 02/02297

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1060772	A	20-12-2000	JP 2000353248 A	19-12-2000
			JP 2000353249 A	19-12-2000
			JP 2000353046 A	19-12-2000
			EP 1060772 A2	20-12-2000
			US 2002072416 A1	13-06-2002

JP 10334275	A	18-12-1998	US 6400364 B1	04-06-2002

US 6005548	A	21-12-1999	RU 2107328 C1	20-03-1998
			RU 2106695 C1	10-03-1998
			AU 3954997 A	06-03-1998
			CN 1231753 A	13-10-1999
			EP 0959444 A1	24-11-1999
			WO 9807129 A1	19-02-1998
			JP 2001504605 T	03-04-2001

US 6061064	A	09-05-2000	US 6351261 B1	26-02-2002
			US 6353436 B1	05-03-2002
			US 6396497 B1	28-05-2002
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